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WARRANTY-GUARANTEE APPLICATION GUIDELINES FOR AIR FORCE GROUND ELECTRONIC EQUIPMENT

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This report presents guidelines for developing and applying warranty-guarantee plans in the acquisition of ground electronic equipment. The plans include warranty at three different maintenance levels, four types of guarantees and possible combinations thereof. Criteria for selecting candidate equipments are provided and the information needed to develop appropriate terms and conditions is also presented. A life-cycle-cost model for use in evaluating the economics of warranty-guarantee versus organic maintenance is also (Cont'd)

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included. The report concludes that, even with characteristics significantly different from avionics equipment, ground electronic equipments are amenable to the use of warranty-guarantee plans. Careful analysis and tailoring of the plans are required to ensure that R&M improvements and cost reductions are achieved.

PREFACE

This report presents guidelines for developing and applying warranty-guarantee in the acquisition of ground electronic equipment. It builds upon previous warranty-guarantee applications within DoD and is intended to assist ground electronic equipment program managers in identifying situations in which warranty-guarantee plans can be effectively applied and in structuring and implementing such plans.

We wish to acknowledge the valuable guidance and assistance provided by Mr. Eugene Fiorentino, Rome Air Development Center, who served as technical monitor for this contract. In addition, we are indebted to many personnel at the Sacramento Air Logistics Center, Air Force Logistics Command, who contributed to this effort.

ABSTRACT

Under Contract F30602-77-C-0217 to Rome Air Development Center, ARINC Research Corporation was tasked to develop concepts and procedures for the application of warranty-guarantee plans to ground electronic equipment. The study was initiated in November 1977 and completed in August 1979.

The plans developed include warranty at three different maintenance levels, four types of guarantees, and possible combinations of warranty-guarantee. Criteria for applying the plans are presented, together with information needed to develop appropriate terms and conditions. A life-cycle-cost model for use in evaluating the economics of warranty-guarantee versus organic maintenance is also described. The approaches presented are then applied to a sample equipment. The report concludes that, even with characteristics significantly different from avionics equipment, ground electronic equipments are amenable to the use of warranty-guarantee plans. Careful analysis and tailoring of the plans to specific equipment applications is recommended.

EVALUATION

1. Reliability Improvement Warranties (RIW) and MTBF guarantees are currently being used within the DoD as a means of improving equipment reliability and reducing support costs. Current application techniques are based primarily on the characteristics of avionic equipment and on the environment in which such equipments are operated and maintained. The objective of this study was to develop alternate warranty-guarantee techniques for application to electronic equipments in the fixed ground environment.

2. The objectives of the study have been achieved. Warranty-guarantee plans have been developed which can be applied, on a selective basis, to a broad range of ground electronic equipment under various maintenance scenarios. Selection criteria for judging the potential of candidate equipment for warranty-guarantee application have been provided. A life-cycle-cost model was also developed for use in evaluating the costs of warranty-guarantee against organic support alternatives. Sample warranty-guarantee contractual provisions have been provided. Warranty administration guidelines and data requirements have also been included in the report. Finally, a sample application of the techniques to a ground electronic equipment was made to provide the prospective user with knowledge of the types of analyses which should be performed prior to application.

3. The report provides guidelines for program offices in structuring, applying, and administering warranty-guarantee arrangements. Proper application can yield significant R&M cost benefits provided that careful analysis and tailoring of the plans to individual equipments is done. The techniques are particularly relevant to cases where minimally attended maintenance concepts are under consideration. Evaluation of post-application results is recommended so that improvements and refinements in the techniques can be made.

Eugene Fiorentino

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Project Engineer

MANAGEMENT SUMMARY

1. INTRODUCTION

Various types of warranty-guarantee plans are currently being used within the Department of Defense as a means of improving equipment reliability and reducing support costs. The majority of these plans are based primarily on characteristics of avionics equipment and on the environment in which avionics equipment is operated and maintained. This document examines the ground electronic equipment environment in relation to existing warranty-guarantee plans.

To establish a basis for subsequent discussion, the following definitions are provided:

- Warranty - a contractual obligation that provides incentives for the contractor to satisfy system field operational objectives of the user. The contractor is given an incentive, through a fixed-price commitment, to repair or replace equipment found to be defective during the period of warranty coverage.
- Guarantee - a commitment embodying contractual incentives, both positive and negative, for the achievement of specified field operational goals.

The purpose of the guidelines presented in this report is to assist ground electronic equipment program managers in identifying situations in which warranty-guarantee plans can be effectively applied and in structuring and implementing such plans. The report examines those ground equipment factors which have an impact on the application of existing warranty-guarantee plans. It then provides plans applicable to the ground environment, provisions for these plans, and criteria for their application. Methods for evaluating the economic implications of using the plans are described. To demonstrate the approaches presented, an application to a sample equipment is also provided. This management summary provides an overview of the guidelines and the general scope of warranty-guarantee application.

2. EXISTING WARRANTY-GUARANTEE PLANS

Table S-1 highlights the principal features of the three basic types of warranty-guarantee plans that have been applied primarily to avionics equipments. The following paragraphs briefly describe the plans; a more detailed explanation is provided in Chapter Two.

Table S-1. FEATURES OF CURRENT WARRANTY-GUARANTEE PLANS

Features	RIW	RIW/MTBF	LSC
Objective	Secure reliability improvement/reduce support costs	Achieve stated reliability requirements/ reduce support costs	Achieve stated logistic-cost goal
Method	Contractor repairs or replaces all applicable items that fail during coverage period; implements no-cost ECPs to improve reliability	Same as RIW; in addition, contractor provides additional spare units to maintain logistic pipeline when MTBF goals are not met	Normal Air Force maintenance; operational test performed to assess LSC; penalty or corrective action required if goals are not achieved
Pricing	Fixed price	Fixed price	Fixed price or limited cost sharing for correction of deficiencies
Incentive	Contractor profits if repair costs are lower than expected because of improved R&M	Similar to RIW, plus possible severe penalty for low MTBF	Award fee if goal is bettered; penalties for poor cost performance

2.1 Reliability-Improvement Warranty (RIW)

The RIW plan commits the contractor to perform stipulated depot-type repair services for a fixed operating time, calendar time, or both, at a fixed price. While the major expenditures of a warranty procurement are for the repair services involved, the primary objectives are to secure reliability improvement and reduce support costs. The question of whether the contractor can provide depot repair services at a cost lower than that of military repair is secondary to the objective of reliability achievement.

2.2 MTBF Guarantee

The MTBF guarantee requires the contractor to guarantee that a stated mean time between failures (MTBF) will be experienced by the equipment in the operating environment. If the guaranteed level is not met, the contractor is typically required to institute corrective action and to provide consignment spares until the MTBF improves.

The MTBF guarantee is normally procured in association with an RIW. An RIW plan provides incentive for MTBF achievement through the contractor maintenance support commitment. The MTBF guarantee provides an even stronger incentive because the contractor is obligated to provide consignment spares to relieve pipeline shortages that may result from low MTBF. The MTBF plan also includes requirements for improving the MTBF to stated values. The added risk the contractor takes in providing this guarantee will be reflected in his bid price. The procurement organization must then determine if the protection provided is cost-effective in relation to the price.

2.3 Logistic Support Cost Commitment

The logistic support cost (LSC) commitment is another means of controlling an equipment's operational effectiveness. Under this plan the contractor makes a contractual commitment regarding a specified LSC parameter, which is quantified through an LSC model. A controlled operational field test is subsequently performed to acquire data for the key variables in the LSC model. The measured LSC parameter is then compared with the contractually specified or target value.

There is considerable variation among LSC commitment plans regarding the action taken as a result of the operational test. Most plans, in the event of achieving a lower measured LSC, provide for an award fee predicated on the amount by which the goal is underrun. In the event of an overrun, the plans provide for reducing or eliminating the award fee. In addition, some plans have required the contractor to take corrective action to achieve the stated goals or be penalized monetarily. In recognition of the risk inherent in this concept, the contractor bids a fixed price for undertaking a commitment where corrective action may be required. These types of plans are considered to fall under or are an adjunct to correction-of-deficiencies (COD) clauses. In the event the cost of correcting deficiencies exceeds the contractor's bid amount, provision may be made for Government and contractor cost sharing of the overrun up to some specified ceiling. Costs beyond the ceiling must be borne solely by the contractor.

3. GROUND EQUIPMENT FACTORS AFFECTING WARRANTY-GUARANTEE

Since existing warranty-guarantee plans were based primarily on characteristics of avionics equipment, a comparison was made between the ground and avionics areas for several different equipment factors. The results of this comparison are shown in Table S-2. An expanded version of this table is provided in Chapter Two, together with a detailed explanation of the

Table S-2. AVIONICS/GROUND EQUIPMENT COMPARISON

Equipment Factors	Avionics	Ground	Impact* of Equipment Factors on Applying Warranty to Ground Equipment as Compared with Avionics
Procurement Responsibility	Relatively centralized	Fragmented	Less uniformity in application of acquisition techniques
Quantities Procured	Relatively high	Relatively low	Less opportunity to spread fixed costs, short production run, reduced competition if relatively low-dollar-amounts contract
Deployment	Significant quantities at individual bases	Small or even one of a kind at individual base	Proficiency of on-equipment maintenance technicians reduced
Wartime-Critical	Generally are	Many are not	Less dependence on military self-sufficiency
Mean Time Between Failures	Relatively low (100s of hours)	Relatively high (1000s of hours)	Less opportunity for improvement
Preventive Maintenance Inspections	Little to moderate use	Extensive use	Increase in induced failures
Redundant/Back-Up Equipment	Little to moderate use	Varies; more frequent use than avionics	Reduced impact of failure, with longer MTTR permitted
Maintenance Concepts/ Personnel	Mostly Air Force	Varies	Increase in options
Transportability	Relatively easy	Frequently difficult, especially without disassembly	Possible requirement for warranty services to be performed at equipment site, or warranty to be at a lower equipment level of equipment that is transportable

*See narrative for additional explanation of impact.

impact of the differences. Four of the most significant aspects of ground equipment are reviewed in the following subsections.

3.1 Procurement Quantity

While occasionally relatively high quantities of ground equipment are procured, in most cases the quantities are small in comparison with avionics equipment. These small quantities may result in relatively small contract dollar amounts and reduced competition. Small quantities also result in short production runs. The consequences are less opportunity to spread fixed costs and the possibility that the entire production run will be completed before the manufacturer receives sufficient operational data to learn of design or assembly problems. The major impact under the RIW concept is that there may be little or no opportunity to incorporate design or production line changes in the remaining items to be produced. However, for small quantities already delivered and in the inventory, it may be feasible to consider requirements for retrofitting the units to incorporate changes.

3.2 Equipment Transportability

For some items of ground equipment, transportability can be a serious problem. For example, the electronics unit of a long-range radar site weighs more than 450 pounds, while the heaviest LRU in the avionics area usually weighs less than 50 pounds. Therefore, many end items of ground electronic equipment cannot be readily transported back to the manufacturer for repair under warranty. As a result, warranty may have to be applied at lower, more transportable levels, such as assemblies or subassemblies. Alternatively, the warranty may require the contractor to perform warranty repairs by traveling to the equipment site.

3.3 Reliability, Maintainability, and Availability Improvement

Ground electronic equipment in the inventory today ranges from 25-year-old tube-type equipment to the most modern solid-state technologies. In the newer items it is not unusual to encounter equipment for which reliability is quoted not as a mean time between failures in operating hours, but as a small number of failures per year. Therefore, for new equipment acquisitions, it may be unrealistic to expect large reliability growths. However, even in cases where there is little potential for reliability growth, there may be potential for improving maintainability or availability.
In some ground equipment applications, maintainability, in terms of maximum duration of downtime, may be more important than the actual number of times the equipment is down. For example, from an operational standpoint, in a long-range air defense radar it may be more advantageous for the equipment to be down five times per day, with a maximum downtime of 5 minutes, than to be down only once per day for a 20-minute period. On the other hand, in training applications it may be more important that the equipment be operationally available without any failures during an eight-hour training period. Because of the diversity in operational missions of ground equipment, a warranty or guarantee on maintainability or availability may be more productive than one on reliability.

3.4 Varied Maintenance Concepts

Maintenance concepts employed in the ground environment are extremely varied. For some ground equipment all on-site maintenance is performed by contractor personnel and failed assemblies or subassemblies are repaired contractually either on-site or at the contractor's facility. Some of these situations may lend themselves quite readily to warranty; others may not. For example, some sites will have a combination of Air Force and contractor maintenance technicians, with removed assemblies and subassemblies repaired at the organization, intermediate, or Government depot. Still other sites use Air Force maintenance technicians exclusively, and all failed assemblies are repaired at a Government depot. For any ground electronic equipment warranty being considered, this broad range of possible maintenance concepts must be taken into account. The following section addresses warranty plans based on the existing maintenance concepts.

4. WARRANTIES ON GROUND EQUIPMENT

Review of existing warranty plans and the ground equipment environment identifies warranty plans applicable at three different levels. These levels correspond to the traditional maintenance levels employed for Air Force ground electronic equipment. Thus the basic types are as follows:

1. Depot Warranty

2. Depot and Field Support Warranty

3. Depot, Field Support, and On-Equipment Warranty

The characteristics of these warranties are shown in Table S-3.

Under the Depot Warranty concept the Air Force provides on-equipment maintenance. The off-equipment, or intermediate-level, maintenance is also performed by the Air Force but is normally limited to verifying that the equipment has failed. The contractor provides depot-level maintenance services under warranty on returned units. Under the second type, Depot and Field Support Warranty, the Air Force also performs on-equipment maintenance; however, all other maintenance is performed by the contractor under warranty. Field support is considered synonymous with intermediate-level maintenance. The distinction is that the support provided by the contractor under a Field Support Warranty replaces the maintenance that the Air Force normally performs at the intermediate level. It is anticipated that the contractor will provide maintenance services to the degree possible at the intermediate level and will limit units returned to the depot to those requiring specialized repair and test facilities or extensive failure analysis. In the third type of warranty plan the contractor is responsible for all maintenance at all levels.

Under each concept the manufacturer accepts the warranty under a fixed-price agreement. The agreement remains in effect for a stated calendar period or a prescribed operational time, or a combination of the two. The

Table S-3. WARRANTY CONCEPTS FOR TRADITIONAL MAINTENANCE LEVELS

Warranty Concept	Equipment Location	Responsibility, Timing, and Extent of Maintenance					
		On-Equipment Level		Off-Equipment Level		Depot Level	
		Timing	Agent	Extent	Agent	Extent	Agent
Depot	Local	Immediate	Air Force	Limited*	Air Force	Full	Contractor
	Remote	Delayed	Air Force	Limited*	Air Force	Full	Contractor
Depot and Field Support	Local	Immediate	Air Force	Full**	Contractor	Limited**	Contractor
	Remote	Delayed	Air Force	Full**	Contractor	Limited**	Contractor
Depot, Field, and On-Equipment	Local	Immediate	Contractor	Full**	Contractor	Limited**	Contractor
	Remote	Delayed	Contractor	Full**	Contractor	Limited**	Contractor

*Under the Depot Warranty, off-equipment maintenance by the Air Force would normally be limited to verifying that a failure had occurred.

**Under this warranty concept it is anticipated that the contractor would, to the extent possible, provide full maintenance services at the intermediate level. Units returned to the depot would be limited to those requiring special repair and test facilities or extensive failure analysis.

objective of each of these warranty concepts is to provide an economic incentive to the contractor to achieve acceptable performance in the field. The obligation to maintain the item under a fixed-price agreement provides the basic warranty incentive mechanism.

A variation to each of the three basic warranty types is made if the installed equipment is in a remote location and is operated without maintenance personnel in attendance. The high reliability of some modern ground electronic equipment may well make such remote operation and maintenance feasible in certain applications. Cost savings can thus be realized as a result of spares pooling and reduced manning. In this situation a maintenance team is dispatched from a central location to perform the on-equipment maintenance. The procedure is comparable to existing Mobile Depot Maintenance. The extended outage of failed equipment may be accommodated by redundant elements of the same equipment or by redundant equipment, or functional coverage may be provided by equipment located at other sites. In this circumstance, maintenance may be intentionally delayed from a few hours to a few weeks depending on the frequency of failure, the amount of redundancy, and the criticality of the system.

A more detailed explanation of the above-described warranties is provided in Chapter Three. As noted therein, these concepts may be found to be cost-effective for many ground systems. In some cases recent trends in the reliability of electronic equipment could reduce the opportunity for reliability improvement. However, there may still be opportunity to improve equipment availability through maintainability improvements or to reduce manning requirements through effective use of contractor maintenance coupled with warranty. In addition, guarantees of various types may be a useful adjunct to a warranty program.

5. GUARANTEES ON GROUND EQUIPMENT

Guarantees (either as a "stand alone" contractor commitment or used in conjunction with a warranty) normally provide a stronger incentive to the contractor than a warranty alone. For example, under a warranty the corrective action usually required is to repair or replace units that fail during the warranty period. However, with a guarantee, various forms of remedy or compensation may be required if the guaranteed performance is not met. Depending on the type of guarantee, these can include (1) money in the form of contract price reduction or loss of award fee; (2) services in the form of engineering analysis or extension of the period of performance; or (3) material in the form of consignment spares, modification kits, or revisions to technical orders.

The following types of guarantees, with their overall objectives, are considered in these guidelines:

Type of Guarantee	Objective
Reliability	Control or reduce frequency of failure
Availability	Control or reduce equipment downtime
Maintainability	Control or reduce expenditure of corrective and preventive maintenance resources
Cost	Control or reduce the resources required to procure and operate a system

These guarantees, either as "stand alone" requirements or coupled with warranties, are described in Table S-4, which shows that numerous combinations are possible. Comments are provided for each combination, together with possible remedies in the event the guarantee is not met. It should be noted that in these plans reliability is not necessarily the primary parameter of interest as is the case in the majority of existing warranty-guarantee applications. In the plans described in Table S-4 it is recognized that recent trends in ground equipment reliability may reduce the opportunity for reliability improvement, but other needed improvements in maintainability and availability are also recognized. Maintenance and support costs and the operational availability of ground equipment are often determined in large part by the maintenance concepts, sparing levels, support equipment, and technical manuals provided by the equipment manufacturer. Inadequacies in any of these areas can significantly increase costs or decrease field operational availability. The warranty-guarantee plans described herein provide a basis for assuring that maintainability, availability, and cost goals are met or, alternatively, provide appropriate remedies in the event these goals are not met. Chapter Four of this report addresses these remedies in more detail and indicates how a warranty and guarantee may be used together to provide complementary incentives. Implementation requirements for each type of guarantee are also included.

6. WARRANTY-GUARANTEE APPLICATION CRITERIA

The proper development of warranty-guarantee provisions requires a great deal of effort on the Government's part to achieve procurement, administration, and logistics implementation. Thus the decision to include warranty-guarantee in a procurement should not be made lightly. To assist potential users in discriminating between warranty-guarantee alternatives and in selecting an approach for a specific application, a number of application criteria have been developed. These criteria are listed in Table S-5 in five areas: procurement, equipment, operational, support, and economic. The criteria are essentially qualitative and can indicate the general feasibility of a specific warranty-guarantee application.

Table [illegible]. POSSIBLE WARRANTY-GUARANTEE PLANS*					
Type of Warranty	Type of Guarantee				
	None	Reliability - MTBF	Availability	Maintainability	Logistic Support Cost
Depot	1. Contractor provides depot-level maintenance	Same as 1, plus contractor guarantees MTBF. If guarantee is not met, contractor provides spares either outright or on a consignment basis. Mandatory retrofit of equipment may also be required	Same as 1, plus guarantees availability in accordance with agreed-upon measurement method. If guarantee is not met, additional spares are provided at no cost to the Government or contract price is reduced. Mandatory retrofit of equipment may also be required.	Same as 1, plus on-equipment maintainability guaranteed in terms of mean time to repair, maximum downtime, or other parameter. If guarantee is not met, penalty could be monetary compensation, improved BITE, revised T.O. troubleshooting procedures, etc.	Same as 1, plus contractor guarantees that on-equipment and intermediate maintenance support cost will not exceed a guaranteed amount. If tests indicate cost is exceeded, either no award fee is paid or contract price is reduced.
Depot and Field Support	2. Contractor provides depot and intermediate or field support maintenance services under warrant.	Same as 2, with guarantee arrangement as stated above.	Same as 2, with guarantee arrangement as stated above.	Same as 2, with guarantee applicable to on-equipment maintenance. Could include maximum time to remove and replace subassemblies, maximum amount of preventive maintenance required, or maximum time to fault-locate.	Same as 2, with guarantee applicable to on-equipment maintenance only. Costs could pertain to training, on-site test equipment, etc.
Depot, Field, and On-Equipment	3. Contractor provides all maintenance. An exception could be to have Air Force provide preventive maintenance only.	Same as 3, with guarantee arrangement as stated above.	Same as 3, with contractor penalized monetarily if guaranteed value is not met.	Not applicable unless subsequent maintenance by Air Force is [illegible]. In this [illegible] contractor may be required to achieve stated maintainability parameters before the [illegible] responsibility transfer. If guarantee is not met, compensation could be monetary or [illegible] maintainability.	Not applicable.
None	Not applicable.	Air Force performs all maintenance. Contractor guarantees that production units will demonstrate a guaranteed MTBF. Additional [illegible] to Government spares provided if guarantee not met. [illegible] including retrofit requirements [illegible] also be mandatory.	Air Force performs all maintenance. Contractor guarantees availability in accordance with [illegible] measurement method. If guarantee is not met, [illegible]	Air Force performs all maintenance. [illegible] If guarantee [illegible] not met [illegible] could [illegible] take corrective action [illegible] BITE, revising T.O. troubleshooting procedures, etc.	Air Force performs all maintenance. Contractor guarantees maximum logistics support cost based on agreed-upon model and tests. If guarantee is not met, award fee may be withheld or corrective actions required

*The intersection of a warranty line and a guarantee column indicates the combination of the two. For example, comments on a depot and field support warranty coupled with a maintainability guarantee are [illegible] at the intersection of the Depot and Field Support line with the Maintainability column.

Table S-5. WARRANTY-GUARANTEE APPLICATION CRITERIA

Criteria	Warranty*						Guarantee**			
	Depot Only		Depot and Field		Depot, Field, and On-Equipment		R	A	M	
	Local	Remote	Local	Remote	Local	Remote				
Procurement Factors										
The procurement is to be on a fixed-price basis.	1	1	1	1	1	1	1	1	1	[illegible]
Multi-year funding for warranty-guarantee is available.	1	1	1	1	1	1	1	1	1	1
Warranty administration can be efficiently accomplished.	2	2	1	1	1	1	1	1	1	[illegible]
The procurement is competitive.	1	1	1	1	1	1	1	1	1	1
Potential contractors have proven capability, experience, and cooperative attitude in providing warranty-guarantee commitments.	2	2	2	2	2	2	[illegible]	2	[illegible]	[illegible]
An escalation clause is included in the contract that is applicable to warranty-guarantee costs.	3	3	3	3	3	3	3	3	3	3
The equipment will be in production over a substantial portion of the warranty-guarantee period.	3	3	3	3	3	3	2	2	2	2
Equipment Factors										
Equipment maturity is at an appropriate level.	1	1	1	1	1	1	1	1	1	1
Unit can be properly marked or labeled to signify existence of warranty-guarantee coverage.	1	1	2	[illegible]	N/A	N/A	[illegible]	[illegible]	2	2
Unit operates independently of other subsystems.	2	2	3	3	N/A	N/A	2	[illegible]	[illegible]	2
Unit has high level of ruggedization when shipment is required.	2	2	3	3	[illegible]	3	2	3	2	3
An elapsed-time indicator (ETI) can be installed on the equipment.	3	3	3	3	3	3	2	[illegible]	[illegible]	[illegible]
Unit has no failure mode that would lead to additional damage to itself or other units if not corrected.	N/A	2	N/A	[illegible]	N/A	2	N/A	N/A	N/A	N/A
Operational Factors										
Use environment is known or predictable.	1	1	1	1	1	1	1	1	1	1
Equipment operational reliability and maintainability are predictable.	1	1	1	1	1	1	1	1	1	1
Equipment wartime or peacetime mission criticality is not of the highest level.	1	1	2	[illegible]	3	3	3	3	3	3
Operational failure and usage information can be supplied to the contractor.	2	2	[illegible]	[illegible]	N/A	N/A	1	1	1	1
Backup warranty repair facilities are available.	3	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Provision can be made for computing the equipment's MTBF.	N/A	N/A	N/A	N/A	N/A	N/A	1	N/A	1	1
Support Factors										
Control of unauthorized maintenance can be exercised.	1	1	2	2	N/A	[illegible]	1	1	1	1
Unit is field-testable.	1	1	1	1	N/A	N/A	2	2	2	2
							Guarantee must recognize testability levels when targets are being established.			
[illegible]	2	2	1	1	1	1	1	1	1	1
Rapid restoral time is required.	N/A	N/A	3	2	3	[illegible]	3	1	3	3
Proper operation may be remotely sensed.	N/A	N/A	N/A	3	N/A	3	3	1	1	3
Economic Factor										
The combination of system reliability, maintainability, deploy-[illegible] information is sufficient to [illegible] warranty-guarantee [illegible] improvements, if necessary.	1	1	1	1	1	1	1	1	1	1

*Numbers refer to relative importance of the criterion for the type of warranty or guarantee. 1 = Major, 2 = Secondary, 3 = Minor. See accompanying text for explanatory comments.
**R = Reliability, M = Maintainability, A = Availability, C = Logistics Support Cost.

In the body of the table, each application criterion has been assigned an "importance factor", which assesses the relative importance of each criterion to each warranty-guarantee plan; however, each user of the table will have to determine the relative importance or applicability of the criteria for his intended use. These factors are interpreted as follows:

1. Major - Failure to meet stated criterion could be grounds for rejecting the plan or, at the least, could require reassessment of the goals or implementation methods.

2. Secondary - Failure to meet stated criterion would generally not be grounds for rejecting the plan. However, special attention must be given this point in developing a specific approach. Several secondary grades for a particular approach could be cause for rejection.

3. Minor - Failure to meet one or more of these criteria is generally not cause for rejecting the plan. However, special consideration should be given to these points in structuring the contract.

It should be noted that in several cases the importance factor changes with different warranty levels or becomes nonapplicable (N/A). For example, warranty administration becomes more critical as the warranty changes from depot only to depot and field, or to depot, field, and on-equipment. In the last case, with the contractor having full responsibility, the Government must have the ability to assure contract compliance at all three levels, not only at the contractor's depot facility. Alternatively, under the depot-only warranty, it is relatively important that the Government be able to provide operational failure and usage information to the contractor. However, under the depot, field, and on-equipment warranty this factor is N/A since contractor representatives will be on site and will be responsible for their own failure and usage information.

The final factor listed in the table, "Economic", is perhaps the most important. Unless sufficient maintenance activity is anticipated to justify its use, a warranty plan will become only a maintenance contract because of low incentives for R&M achievement. In addition, guarantee compliance will be judged on the basis of highly variable quantitative estimates, which may be challenged by a contractor if he is subjected to significant cost impacts. A complete analysis of warranty-guarantee potential, especially from the economic viewpoint, cannot be made until price and implementation proposals are received from the bidding contractors. The criteria listed in Table S-5 must therefore be viewed as an initial means of screening to select those procurements for which the effort in developing warranty-guarantee clauses is believed to be worthwhile. The source-selection activity, coupled with an economic analysis, must be used for the final screening and decision on whether to implement warranty-guarantee provisions as part of the system acquisition.

7. ECONOMIC ANALYSIS

A key element in the decision to use a warranty-guarantee is an analysis of the cost of this approach in comparison with the cost of organic maintenance. An economic model was developed for use in evaluating the expected life-cycle cost (LCC) of the two alternatives. Appendix A is a detailed description of the model.

The model is applied to evaluate the life-cycle cost of the warranty approach against that of organic support. It incrementally analyzes these costs for various warranty periods and, in conjunction with varying the data inputs to reflect alternative conditions, can aid in developing an effective warranty procurement. If an MTBF guarantee is applied, the model will also compute the quantity of consignment spares due, if any, and the resulting LCC savings. Chapter Six, which contains a complete discussion of economic analysis, also identifies methods for estimating guarantee costs and the value of a guarantee to the Air Force.

8. WARRANTY-GUARANTEE PROVISIONS

A key ingredient in any successful warranty-guarantee program is the contract section that contains the warranty-guarantee provisions. The provisions typically include the following three major parts:

Part I - Statement of Contractor Warranty-Guarantee

Part II - Contractor Obligations

Part III - Government Obligations

When a warranty-guarantee includes contractor maintenance at other than the depot level only, it may be necessary to prepare a separate statement of work (SOW) to describe the services to be performed. For example, at an operational site a contractor could provide warranty maintenance on equipment he had delivered; and on other Government-furnished equipment at the site, he could provide maintenance under a services contract. In these circumstances a separate SOW may be required. Guidelines for structuring warranty-guarantee provisions are presented in Chapter Seven. Appendix D provides specific language that may be used to construct provisions, and Appendix E contains an outline for an accompanying SOW in the event it is required.

9. WARRANTY-GUARANTEE ADMINISTRATION

The success of a warranty-guarantee procurement will depend in part on proper Government management. Table S-6 lists some of the major activities that should be accomplished for successful implementation of warranty-guarantee plans. Experience has shown that a critical factor is early coordination between the procuring organization, the Air Logistics Center within AFLC that will be managing the equipment after it is deployed, the

Table S-6. MAJOR ACTIVITIES FOR IMPLEMENTING WARRANTY-GUARANTEE PROVISIONS

• Review contract provisions
• Verify using organizations and equipment deployment
• Review and update installation schedule
• Identify and monitor Air Force test and evaluation procedures
• Identify allowable Air Force maintenance actions
• Document failure-verification procedures
• Indoctrinate and train personnel
• Review contractor data plan

DCAS organization that will be responsible for contract administration at the contractor's facility, and the using command(s). Experience gained by these organizations in implementing warranties over the past four to five years should pave the way for successful implementation of the plans introduced herein.

10. CONCLUSIONS

The following principal conclusions have been reached on the basis of the guidelines presented herein:

- As compared with avionics equipments, which constitute the bulk of warranty experience to date, ground electronic equipments are very diverse in terms of equipment types and operational and maintenance scenarios.
- Diversity in ground electronic equipments requires that special consideration be given to many factors that have an impact on warranty planning and evaluation.
- In some cases recent trends in the reliability of ground equipment may reduce the opportunity for reliability improvement, but there may be opportunity to improve operational availability and to reduce maintenance and support costs.
- Several alternative warranty-guarantee plans are possible in the ground electronic equipment area: analysis is required to determine the most suitable, and the plans must be tailored to meet the special circumstances of individual procurements.
- Special circumstances (e.g., small quantities) often present in ground equipment procurements indicate that economic analysis is one of the most significant evaluation criteria. The economic model developed herein provides a key tool for this analysis.

11. RECOMMENDATIONS

While this study identified a number of unusual characteristics of ground electronic equipments, it also provided a range of possible warranty-guarantee plans which, depending on specific circumstances, can be effectively applied. The following recommendations are provided regarding the use of these guidelines:

- Adequate procurement lead time must be scheduled to permit warranty-guarantee planning and analysis.
- Warranty-guarantee provisions should be tailored to specific procurements and to the objectives of the warranty-guarantee application.
- Since several of the plans developed herein are as yet untried in actual procurements, they should be exercised with care.
- The final decision to use any form of warranty-guarantee for the acquisition of ground electronic systems should be based on an economic analysis during the evaluation of contractor proposals.

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CHAPTER ONE

INTRODUCTION

1.1 PURPOSE

The guidelines presented herein were developed to provide Air Force program managers information concerning the selection and application of various warranty-guarantee plans to electronic equipment in the fixed ground environment. For selected applications warranties are considered to have the potential for providing an effective means of controlling life-cycle costs and increasing system reliability. However, it should not be assumed that warranties will be effective in every situation. More important, it should not be assumed that warranty-guarantee plans previously developed for other types of equipment (e.g., avionics) are readily transferable and applicable to electronic equipment in the fixed ground environment. It is the purpose of this guide to assist ground electronic equipment program managers in identifying situations in which warranty-guarantee plans can be effectively applied and in structuring and implementing such plans.

Although further distinction between warranty and guarantee plans will be made in subsequent chapters of this report, the following definitions are initially provided:

- Warranty - a contractual obligation that provides incentives for the contractor to satisfy system field operational objectives of the user. The contractor is given an incentive, through a fixed-price commitment, to repair or replace equipment found to be defective during the period of warranty coverage.
- Guarantee - a commitment embodying contractual incentives, both positive and negative, for the achievement of specified field operational goals.

1.2 BACKGROUND

Various types of warranty-guarantee plans are currently being used within the Department of Defense as a means of improving equipment reliability and reducing support costs. The majority of these plans were based on guidelines provided in RADC TR 76-32, "Guidelines for Application of Warranties to Air Force Electronic Systems." The guidelines presented

in that report are based primarily on the characteristics of avionics equipment and on the environment in which avionics equipment is operated and maintained. Avionics equipment normally consists of small transportable units produced in large production quantities. The circumstances under which they are operated and maintained are essentially the same for all equipment types. Contrasted to the homogeneity of avionics equipment is the diversity found in the ground electronics area. Basic differences include maintenance and design concepts, equipment transportability, deployment quantities, and reliability and maintainability characteristics.

Although agreement on the effectiveness of warranty-guarantee plans is not universal within DoD, the continued and expanding use of such plans indicates an acceptance of their potential for improving reliability and reducing support costs. The plans also have the same potential for application to ground electronic equipment. However, the basic differences between the characteristics and environment of ground electronic equipment and those on which existing warranty-guarantee plans were based make it necessary to develop new or revised warranty-guarantee approaches.

1.3 TECHNICAL APPROACH AND DOCUMENT SCOPE

The technical approach to completing these guidelines is illustrated in Figure 1-1. The tasks indicated are those set forth in the statement of work under Contract F30602-77-C-0217. Equipments to be used as study vehicles were identified and baseline data were collected through visits and discussions with representatives of ground electronic equipment development, operation, and support organizations. The ground electronic equipment environment defined by these activities is described in Chapter Two of this report. Commercial warranty practices associated with ground electronic equipment were surveyed through visits to several different commercial concerns. The results of this survey are also discussed in Chapter Two.

Before formulating warranty-guarantee concepts, we reviewed existing warranty-guarantee plans and lessons learned from current warranty programs. Where practical, the warranty-guarantee plans presented herein were adapted from existing concepts. In some areas it was necessary to develop new concepts and plans. Chapters Three and Four are discussions of the warranty-guarantee plans required to meet the special circumstances of ground electronic equipment. Criteria for applying these plans were then developed, as described in Chapter Five.

Chapter Six addresses the economics of the plans developed and provides information on the life-cycle-cost model. Typical warranty-guarantee provisions for the plans are described in Chapter Seven, and administrative and data requirements in Chapter Eight. Chapter Nine demonstrates how the approaches presented would be applied to a sample equipment being procured. Chapter Ten provides conclusions and recommendations regarding use of these guidelines.

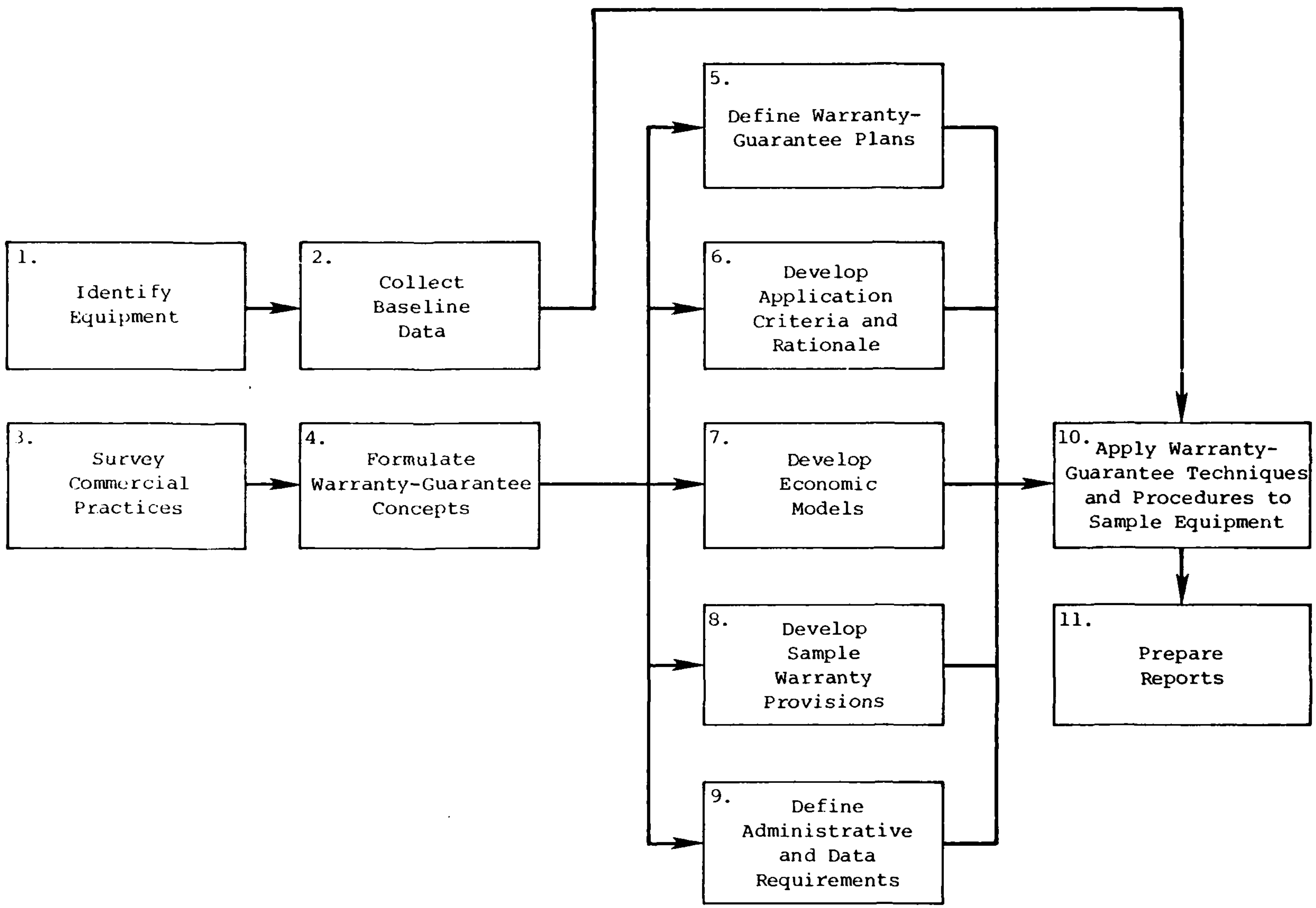


Figure 1-1. TASK FLOW

A series of supporting appendixes is also presented:

A - Mathematical Model and Computer Program for Organic versus Warranty LCC Analysis

B - MTBF Growth Model

C - Spares Subroutine

D - Provisions for Warranty and MTBF Guarantee Plans

E - Statement of Work (SOW) Outline For Use with Warranty/Guarantee

F - Data Item Description - Reliability Improvement Warranty (RIW) Data Reporting and Summary Reports

G - Data Item Description - Reporting Materiel Transactions Contractor Storage/Distribution Point

CHAPTER TWO

EXISTING WARRANTY PLANS AND THE GROUND ELECTRONIC ENVIRONMENT

This chapter consists primarily of background information. It first provides an overview of existing warranty plans and then describes the ground electronic equipment environment. Several important ground equipment factors that could have an impact on warranty considerations are cited.

2.1 COMMERCIAL WARRANTIES

To determine whether the commercial sector was using any warranty-guarantee concepts that might be applicable to this study, discussions were held with several different companies. Table 2-1 lists the types of equipments that these companies either bought or sold and the primary warranty-related discussions pertaining to the equipment. As noted in the table, a wide variety of equipments and warranty-related subjects were included. The overall conclusion of these discussions was that there was little in the warranty-guarantee concepts of the commercial sector that would be applicable to Air Force ground electronic equipment. Both buyers and sellers in the commercial sector considered warranty as a marketing tool: the buyers took advantage of a standard commercial warranty when it was available, and the sellers offered warranties to meet competition or gain a competitive advantage. There were no formal warranty-guarantee plans comparable to those discussed in the following sections.

2.2 MILITARY WARRANTIES

2.2.1 Background

Although the use of warranties in military procurements is not new, until the mid 1970s the warranties applied were the traditional correction-of-deficiency (COD) or latent-defect clauses. In addition, the warranties were usually of short duration (90 days to 1 year) with respect to the life of the equipment (5 to 20 years). In the early and mid-1970s, under RADC sponsorship, warranty agreements between commercial airlines and their equipment suppliers were studied. The objective of the study was to determine whether such warranty arrangements could be applied in the Air Force acquisition process. A product of this study was the previously mentioned

Table 2-1. SURVEY OF COMMERCIAL WARRANTY-GUARANTEE PRACTICES	
Equipment	Primary Subjects Discussed
Control unit for Communications Addressing and Reporting System Computer-controlled switching system	Warranty-guarantee coupled with contractor maintenance, warranty-guarantee cost, and warranty transferability
Microwave transmission equipment	Commercial warranties, warranty negotiation, and warranty pricing
Low-noise amplifiers; cryogenic compressors; and various items of digital communications equipment, including shipboard communications terminals	Commercial acquisition techniques, including use of warranty-guarantee, warranty administration, maintenance technician proficiency
CRTs, power supplies, and various commercial consumer products	Trends in commercial warranty practices
Conveyor systems	Commercial warranty terms and price
Computer-directed control systems	Commercial warranty terms and assistance in fault isolation during warranty
Antennas and servomechanisms, amplifiers, transmit and receive ground communications equipment, and diesel and uninterruptable power supplies	Commercial acquisition techniques, the impact of warranty on provisioning, failure analysis and in-house repair of warranted equipment
Shipboard navigation equipment	Warranty in relation to marketing commercial equipment, warranty cost, and support continuity guarantees
Air compressors and self-propelled work platforms	Commercial warranty terms and conditions

RADC TR 76-32, which contained guidelines for applying warranties to Air Force electronic systems. The guidelines addressed three basic types of warranty plans: Reliability Improvement Warranty (RIW), MTBF Guarantee, and Logistic Support Cost (LSC) Guarantee. The following sections briefly address each of these plans. It is emphasized that the plans were fully developed in the previous guidelines and not developed again herein.

2.2.2 Reliability-Improvement Warranty (RIW)

An RIW plan commits the contractor to perform stipulated depot-type repair services for a fixed operating time, calendar time, or both, at a fixed price. While the major expenditures of an RIW procurement are for the repair services involved, the prime thrust of the approach is to achieve acceptable reliability. The question of whether the contractor can provide depot repair services at a cost lower than that of military repair is secondary to the objective of reliability achievement and reduced support cost.

Reliability-improvement warranties are negotiated in association with the production contract and apply to the operational use of the production items. Because of the long-term commitment being made by the contractor, warranty service is recognized as a separate cost item that the prospective contractors are asked to quote as a separate line-item option. This approach provides the Government the opportunity to evaluate the economics of the warranty versus nonwarranty procurement, with consideration given to the reliability and maintainability differences between the two alternatives. Warranty funds have been obtained from both production and operation/maintenance sources. If operation/maintenance funds are to be used, incremental funding for long-term warranty is necessary since this fund category can be committed on an annual basis only.

If the RIW is applied, it is necessary to establish an agreement setting forth the terms and conditions for the warranty. A typical agreement should include:

- Statement of Contractor Warranty. This section contains the basic agreement, requirements for corrective action, exclusions and limitations, extent of warranty coverage, requirements for maintenance facilities, and cost-related information.
- Contractor Obligations. This section includes collateral contractor obligations regarding ECPs, warranty marking and seals, repair turnaround time and penalties, and data requirements.
- Government Obligations. This section provides details on administration, timely approval of ECPs, and provision of data to the equipment manufacturer.

2.2.3 MTBF Guarantee

The MTBF guarantee requires the contractor to guarantee that a stated MTBF will be achieved by the equipment in the operating environment. If

the guaranteed level is not met, the contractor is typically required to institute corrective action and to provide consignment spares until the MTBF improves.

The MTBF guarantee is normally procured in association with an RIW. An RIW plan provides incentive for MTBF achievement through the contractor maintenance support commitment. The MTBF guarantee provides an even stronger incentive because the contractor is obligated to provide consignment spares to relieve pipeline shortages that may result from low MTBF. The MTBF plan also includes requirements for improving the MTBF to stated values. The RIW and MTBF plans are considered totally compatible.

Because of possible problems in determining the relevancy of failures, the MTBF plan is considered feasible only where the contractor either performs the maintenance (RIW or contract maintenance) or can monitor the maintenance process. Such restriction is also necessary for assuring that the contractor has an opportunity to develop effective corrective actions.

The MTBF provisions cover the following topics:

- Basic Guarantee. A schedule of MTBFs required to be met by the equipment in the field for specified periods is established.
- MTBF Definition. Countable failures are defined, and the time base for computing MTBF is stated.
- Compliance Determination. Frequency of MTBF measurement is specified, together with a formula for computing consignment-spares requirements in the event the unit does not meet MTBF requirements.
- Contractor Corrective Action Requirements. The additional action to be taken by the contractor to achieve the required MTBF levels is stated.
- Consignment-Spares Administration. Provisions are outlined for spares obligation, delivery, Government return, and ownership conversion.
- Data Requirements. Data to be developed by the contractor in support of the MTBF guarantee are specified.

In recognition of the added risk the contractor takes in offering this guarantee, the contractor will include his price for this protection in his bid, perhaps as a separate line item, if so directed by the Government. The procuring agency must then determine if the protection provided is cost-effective in relation to the contractor's price.

2.2.4 Logistic Support Cost Commitment

Use of the logistic support cost (LSC) commitment is another means of controlling an equipment's operational effectiveness. Under this plan the contractor makes a contractual commitment regarding the cost to support the

equipment in the field. Individual parameters such as MTBF, MTTR, etc., are estimated and quantified through an LSC model. A controlled operational field test is subsequently performed to acquire data for the key variables in the LSC model. The measured LSC parameter is then compared with the contractually specified or target value.

There is considerable variation among LSC commitment plans regarding the action taken as the result of the operational test. Most plans, in the event of achieving a lower measured LSC, provide for award fee predicated on the amount by which the cost goal is underrun. In the event of an overrun, the plans provide for reducing or eliminating the award fee. In addition, some recent plans have required the contractor to take corrective action to achieve the stated goals or be penalized monetarily. In recognition of the risk inherent in this concept, the contractor bids a fixed price for undertaking a commitment where corrective action may be required. These types of plans are considered to fall under, or are an adjunct to, correction-of-deficiencies (COD) clauses. In the event the cost of correcting deficiencies exceeds the contractor's bid amount, provision may be made for Government and contractor cost sharing of the overrun up to some specified ceiling. Costs beyond the ceiling must be borne solely by the contractor.

2.3 THE GROUND ELECTRONIC ENVIRONMENT

2.3.1 Differences in Avionics and Ground Equipment Environments

Section 2.2 summarized existing warranty-guarantee plans that have been used in DoD acquisitions. Since they were formulated and applied primarily for avionics equipments, it is important now to consider the ground equipment area and its environment in relation to avionics. To permit a review of the ground equipment environment, several items of equipment were identified as study vehicles. These equipments and some of their major characteristics are listed in Table 2-2. This chapter's discussion of ground equipment factors and their impact on warranty application is based in part on our review of these equipments.

The most obvious difference between the ground and avionics environments is the diversity of ground electronic equipment. For example, a major Air Force Air Logistics Center managing ground electronic equipment is responsible for more than 2000 different end items. These items differ considerably in complexity, quantities deployed, and support concept. Such diversity makes it difficult to generalize; however, Table 2-3 provides an overall comparison of several factors for the two different environments and shows their impact on warranty application. The following subsections address several aspects of the ground equipment environment that will have an impact on warranty considerations.

Table 2-2. CHARACTERISTICS OF EQUIPMENT SELECTED FOR WARRANTY-GUARANTEE STUDY

Type Model/Series (TMS)	Nomenclature	Functional Grouping/System	Contractor	Vintage	Quantity	User
Inventory Equipment						
[illegible]A-124	Coder/Decoder Group	Radar	Hazeltine	1971	102	ADCOM
[illegible]-171	UHF Multi-Channel Radio	Communications	Collins	1976	2534	TAC and AFCS
[illegible]	Solid State ILS	Landing	Texas Instruments	1975	60	AFCS
FY[illegible]-47	Coordinate Data Transmitting Set	Radar	Burroughs	1972	63	ADCOM
[illegible]-97	Troposcatter Radio Set	Communications	RCA	1960's	310	TAC and AFCS
New-Acquisition Equipment						
[illegible]	Solid State ILS	Landing	Wilcox	1977	123	AFCS
[illegible]-42	Radar IFF Set	Air Traffic Control (Radar)	Cutler-Hammer (AIL)	1977	150	AFCS

Table 2-3. AVIONICS/GROUND EQUIPMENT COMPARISON

Equipment Factors	Avionics	Ground	Impact* of Equipment Factors on Applying Warranty to Ground Equipment as Compared with Avionics
Procurement Responsibility	Relatively centralized	Fragmented	Less uniformity in application of acquisition techniques
Wartime-Critical	Generally are	Many are not	Less dependency on military self-sufficiency
Quantities	Relatively high	Relatively low	Less opportunity to spread fixed costs, short production run, reduced competition if relatively low-dollar-amount contract
Redundant Back-Up Equipment	Little application	Varies; more frequent use than avionics	Smaller impact of failure, permitting longer MTTR
BITE	Use increasing greatly	Minor increase in use	Reduced MTTR, facilitating two-level maintenance
Deployment	Significant quantities at individual bases	Small or even one of a kind at individual base	Reduced proficiency of on-equipment maintenance technicians
Measurement of Operating Time/Usage	Relatively precise -- flying hours/ETI's	Estimate -- 24 hours per day	Difficulty in computing reliability
Cannibalization Opportunity	High	Little	Increase in unauthorized maintenance, but decrease in "suitcases" of bad parts
MTBFs	Relatively low (100s of hours)	Relatively high (1,000s of hours)	Less opportunity for improvement
EMI	Little to moderate use	Extensive use	Increase in induced failures
Failure Definition	Relatively easy	Sometimes Difficult	Increased RTOKs, subjective influences
Maintenance/Operations Relationship	Maintenance generally, with operations intermittent	Operations generally, with maintenance intermittent	Degradation of maintenance planning
Maintenance Personnel	Mostly Air Force	Varies	Increased options

*See narrative for additional explanation of impact.

2.3.2 Procurement Factors

2.3.2.1 Procurement Responsibility

In the avionics area, procurement responsibility is relatively centralized within the Air Force Systems Command (AFSC) at the Aeronautical Systems Division (ASD) and the Electronics Systems Division (ESD). On occasion the Air Force Logistics Command will procure newly developed avionics equipment, but not as frequently as AFSC. However, this centralization does not apply to ground electronic equipment. Not only do AFSC and AFLC make a large number of purchases; such activity is commonplace in individual operating commands, e.g., TAC, ADCOM, and AFCS. The result is that any guidelines developed will be employed by a larger number of procurement organizations and possibly subjected to different interpretations. Although uniformity, in terms of a "cook book" approach, is not essential, consistency and standardization of contractual terms and conditions are desirable. It is important to tailor warranty terms and conditions to a specific application; in the ground area, the number of specific applications is extremely large. Contractors understandably view any warranty-guarantee program as one that increases their risk. When they are dealing with a large number of different procurement activities and varied warranty approaches, they may view the ground area as an even greater risk.

2.3.2.2 Procurement Method in Relation to Development Required

While there are some examples of basically commercial purchases of avionics equipment (Air Force Carousel INS or ARMY VOR/ILS), the majority of avionics procurements proceed through competitive development and test programs before a production contract is awarded. During the validation or engineering development programs, contractors have the opportunity to influence the design in such a way that field operational reliability and maintainability are enhanced. Ideally, under the expectation of warranty-guarantee provisions in the contract, the manufacturers will do just that. As opposed to the typical avionics development programs, ground electronic equipment procurements normally fall into one of three categories:

1. One or more manufacturers are already producing equipment that meets all or most of the requirements. The equipment is basically available off the shelf (OTS).
2. While equipment to meet the requirement is not being produced, the technology and components needed to produce the equipment are readily available to several manufacturers. Some engineering/development and production start-up is required.
3. Neither existing equipment nor technology and components to design and produce the equipment are readily available; a development and validation program comparable to typical avionics programs will be required.

In the first two cases, a two-step procurement will often be used since little or no development is required. In the first case, the manufacturers

may be requested to submit bid samples for testing. Those providing equipment that meets or exceeds the requirements are then invited to submit cost proposals. In the second case, bidders will be asked to submit technical proposals rather than bid samples. After the technical evaluation is completed, those bidders with technically acceptable proposals will be requested to submit cost proposals. The third case is comparable to the second except that before starting production, some degree of development is required.

The existing warranty concepts correctly indicate that the earlier the decision is made to consider warranty the greater the potential for maximum benefits. However, the two-step procurement method, which is used for many ground equipment acquisitions, provides minimum notification of intent to use warranty. In the first case, the bidders are already "locked in" to the reliability and maintainability built into their existing equipment. In the second case, while they have latitude in design, component selection, and system integration, the same opportunities for R&M design are not available as in the third case, which is comparable to the typical avionics development program. The ground equipment area thus offers more opportunity for purchasing OTS equipment and for using the two-step procurement method; however, it should be recognized that the same incentive mechanisms will not be present. As opposed to incorporating improvements in additional production units, it may be necessary for the manufacturer to retrofit improvements in items already delivered.

Another aspect of the two-step procurement method in relation to warranty considerations is the time required to complete the procurement. One of the advantages of the two-step method is that time is usually saved in deploying the equipment. However, a well structured warranty plan requires time to prepare. Thus, the program manager should recongize that warranty and the two-step procurement method may have opposite effects on the time required to complete the procurement. However, in the ground equipment area, as in the avionics area, adequate warranty planning time is considered a necessary condition for a successful warranty program and should not preclude using a warranty in conjunction with two-step procurements.

2.3.2.3 Procurement Quantity

Avionics procurement quantities vary from a number required to equip one type or series aircraft to an across-the-total-fleet number. The number typically varies from several hundred to several thousand. [In the case of the ARN-118(V) TACAN, it was almost 10,000.] While there are cases in the ground electronic area where the quantities procured are relatively large, in many cases only small quantities are involved. If this results in a relatively small contract dollar amount, the number of competitors willing to bid will often be reduced. The small quantity also results in short production runs and less opportunity to spread fixed costs. The entire production run might be completed before the manufacturer receives sufficient operational usage data to learn of design or assembly

problems. Under the RIW concept there would be little or no opportunity to incorporate design or assembly changes in the remaining production items. However, for small quantities of ground equipment already delivered and in the inventory, it may be feasible to consider requirements for retrofitting the units to incorporate changes.

2.3.3 Equipment Factors

2.3.3.1 Equipment Maturity

Warranty is not usually applied to items that require extensive or revolutionary development, because of the inherent risk. Neither are mature designs considered likely candidates, because of the lack of potential for reliability improvement. While both of these extremes are encountered in the ground electronic area, the most likely situation is extremely high MTBFs in relation to the avionics area. For many ground equipments the expected failures are stated in terms of one or two per year. Under these circumstances many ground equipment items may not be likely candidates for reliability-improvement warranty. However, while the procuring activity may not foresee the possibility of reliability improvement, it may want contractual assurance that the stated reliability will be met. Under these circumstances a reliability assurance or some form of guarantee may be more appropriate for many items of ground electronic equipment. This aspect will be considered in more detail in subsequent sections of this report.

2.3.3.2 Varied Maintenance Concepts

Nowhere is the difference between avionics equipment and ground equipment more evident than in maintenance concepts employed. In general, avionics maintenance is relatively homogeneous, while in the ground environment it is extremely varied. For example, on some ground equipment all on-site maintenance is performed by contractor personnel and replaced assemblies/subassemblies are repaired contractually either on-site or at the contractor's facility. Some of these situations may lend themselves quite readily to warranty; others may not. For example, some sites will have a combination of Air Force and contractor maintenance technicians, and removed assemblies/subassemblies will be repaired at the organization, intermediate, or Government depot. Still other sites use Air Force maintenance technicians exclusively, and all failed assemblies are repaired at a Government depot. There are also Programmed Depot Maintenance (PDM), accomplished on a scheduled basis by Government or contractor personnel, and Emergency Maintenance Teams available for on-call situations. For any warranty on ground electronic equipment, this broad range of possible maintenance concepts must be considered.

2.3.3.3 Unauthorized Maintenance

Unauthorized maintenance may be a problem in the ground equipment environment, particularly at remote sites. In the avionics area an aircraft can normally be brought back into commission by cannibalizing an

LRU from another out-of-commission aircraft. When the proper authorization is obtained, this is a completely acceptable procedure. However, in the ground environment there are seldom additional unused equipments available to permit cannibalization. If the needed spare part, subassembly, or assembly is not available, maintenance technicians will frequently attempt repair, knowing that repair is not officially authorized. The only alternative is to keep the equipment out of commission (often for extended periods) until a spare is obtained. Under these circumstances they feel that they have little to lose by attempting to repair the failed unit.

In existing warranty plans labels are usually applied to the equipment to indicate warranty coverage and seals are installed to preclude unauthorized maintenance. The warranty provisions normally provide that in the event of seal breakage, repair of the unit will not be covered under the warranty. For this reason, it is expected that the percent of returned units excluded from warranty repair because of seal breakage will probably be higher for ground equipment than for avionics, particularly at remote sites. As a result, this aspect deserves additional emphasis in planning and structuring warranty provisions on ground equipment and in training maintenance personnel.

2.3.3.4 Preventive Maintenance Inspections (PMIs)

In addition to the circumstances that could result in unauthorized maintenance, preventive maintenance inspections commonly conducted on ground equipment could further add to warranty exclusions. Studies have indicated that many items of ground electronic equipment have entirely too many PMIs. It is not unusual to see essentially solid-state devices being inspected at intervals of 1, 7, 14, 28, and 91 days. During these inspections, unnecessary adjustments are often made merely because the technician is there. There is, in effect, more opportunity for tampering and induced failures. In addition, during these PMIs, when spare LRUs are available, they are often exchanged with operating LRUs to verify that the spares are operational. Thus, for ground equipment under warranty, it may be necessary for manufacturers to evaluate more carefully the extent of or need for PMIs that they now recommend. In addition, procedures for performing PMIs so as not to void the warranty must be clearly stated.

2.3.3.5 Unnecessary Maintenance

Although unnecessary maintenance was mentioned in the preceding subsection, another aspect of such maintenance in the ground environment is worthy of note. Again, it is best explained by a comparison with aircraft avionics maintenance. Aircraft are normally under the control of maintenance, with periodic operations scheduled; however, many items of ground electronic equipment are normally in the hands of the operator, with periodic maintenance scheduled. In addition, the nature of certain ground equipment operations necessitates the presence of a maintenance technician. As a result, there are many joint operator/maintenance activities that, for instance, may be to adjust a presentation to the particular taste of an operator. While such "tweaking" is desirable from the operator viewpoint,

this may also result in an induced failure that would not be covered under warranty.

This subsection and the two previous ones have addressed maintenance aspects of ground electronic equipment that could have an impact a warranty. The presence of seals and warranty labels on the equipment lessens the opportunity to take actions that could result in warranty exclusions. However, it is expected that for ground equipment additional emphasis will be needed to have the manufacturer clearly state those maintenance actions which may be taken without voiding the warranty.

2.3.3.6 Reliability, Maintainability, and Availability Improvement

Ground electronic equipment in the inventory today ranges from 25-year-old type equipment to the most modern solid-state technologies. Of the newer items it is not unusual to encounter equipment for which reliability is quoted not as a mean time between failures in operating hours but as a certain number of failures per year. Therefore, for some new equipment acquisitions, it may be unrealistic to expect much improvement in reliability. However, even in cases where there is little potential for reliability growth, there may be potential for improving maintainability or availability. In some ground equipment applications maintainability, in terms of maximum downtime, may be more important than the actual number of times the equipment is down. For example, from an operational standpoint, in a long-range air defense radar, it may be more advantageous for the equipment to be down five times per day, with the maximum duration of any downtime not exceeding 5 minutes, than to be down only once per day for a 20-minute period. On the other hand, in training applications, it may be more important that the equipment be operationally available without any failures during an eight-hour training period. Because of the diversity in operational missions of ground equipment, a warranty or guarantee on maintainability or availability may be more productive than one on reliability. The concepts introduced in Chapters Three and Four will address these alternatives in more detail.

2.3.3.7 Redundancy

Many items of ground electronics equipment -- for example, those at a radar or communications site -- have back-up or redundant equipment on standby. Redundancy is also commonly used on ground landing and navigation systems, where safety is essential. This lessens the impact of failure of the primary equipment and also allows more time to repair the item while still permitting achievement of availability goals. Redundancy may also permit lower levels of manning. For example, with a redundant system maintenance personnel can complete ongoing maintenance actions and need not be immediately interrupted because of a failure. Redundancy should also have a favorable impact on warranty by reducing the need for unauthorized maintenance actions.

2.3.3.8 Equipment Transportability

For some items of ground equipment, transportability represents one of the biggest differences from avionics equipment. For example, the electronics unit of the FYQ-47 Transmitting Set (part of a long-range radar site) weighs more than 450 pounds, while the heaviest component in the avionics area usually weighs less than 50 pounds. Therefore, many end items of ground electronic equipment cannot be readily transported back to the manufacturer for repair under warranty. As a result, warranty may have to be applied at lower levels, such as assemblies or subassemblies, which are transportable. Alternatively, the warranty may require the contractor to perform warranty repairs by traveling to the equipment site.

2.3.4 Operation Factors

2.3.4.1 Operating Time/Usage

Warranty contracts, particularly those with an MTBF guarantee, normally require a method to measure the equipment operating time. For avionics the method used may be aircraft flying time converted to operating time through use of an appropriate k factor, or the installation of an elapsed-time indicator (ETI) on the warranted unit. For ground electronic equipment, with some exceptions, operating time is not normally logged. The usual practice, depending on the objective of the computation, is to assume 24 hours per day 30 days per month as equipment operating time. Warranty on ground electronic equipment may thus require more precise operating-time measurements than those currently computed. However, because the equipment is fixed geographically, in contrast to the mobility of avionics equipment, operating-time logs could be easily maintained; or, as with avionics equipment, an ETI could be installed. The ground equipment program manager considering warranty must recognize the need for new approaches to operating-time measurements. This aspect is discussed in more detail in Chapter Eight.

2.3.4.2 Deployment Quantity and Maintenance Proficiency

Many ground equipment items are deployed in very small quantities. For example, there may be one to 10 of an item at a base or site. A major result is that maintenance technicians tend to lose proficiency, especially if there are only one or two of the item and they demonstrate reliability such that there are only one or two failures per year. A technician may arrive at a site from a training school very proficient in fault-isolation and repair procedures, only to lose this proficiency as a result of little actual "hands on" experience. Thus, when a failure does occur, the time to fault-isolate and repair may be considerably greater than that demonstrated in a maintainability test, during which technician proficiency is high. Therefore, any warranty analysis, especially one involving maintainability or availability of the equipment, must consider not only the inherent maintainability or availability of the equipment but also the deployment quantities at different locations and the ability of technicians to maintain proficiency in their individual operating environments.

2.3.4.3 Deployment Location

Many items of ground electronic equipment are deployed at Air Force Bases and receive basically the same logistics support as avionics equipment. In these cases, Base Supply, which stocks spares, is usually located close by; and other needed facilities, such as the Reparable Asset Control Center (RACC), support both ground and avionics equipment. A centralized processing facility at a base aids considerably in implementing any special reparable processing procedures required under warranty. For example, the RACC can verify that failure-circumstance documentation accompanies the equipment back to the manufacturer for repair. If the documentation is not completed, RACC personnel can readily obtain it from the maintenance activity collocated on the base.

In contrast to the base environment, many other items of ground equipment are deployed at a remote location or, particularly in TAC, may be mobile equipment not permanently fixed at a single location. In these situations, maintenance and supply procedures are considerably different. For example, at some remote sites within the CONUS, weekly "runs" may be made to the closest Air Force Base, where reparable items are turned in to base supply and replacement items are obtained. At other sites, usually remote outside the CONUS, air transportation is the only means of supply. Resupply times are scheduled and emergency supplies are provided on an on-call basis. Maintenance support beyond that locally available at the site is also on an as-needed basis. Where the equipment is deployed at remote sites, implementation of any special reparable processing procedures under warranty would be more difficult. In the structuring of warranty provisions for ground equipment, the potential impact of the deployment locations will require careful consideration.

2.3.4.4 Failure Definition

Warranty terms and conditions usually contain a definition of what constitutes a failure for warranty purposes. A definition is needed to establish contractor responsibility for warranty repairs or to relieve the contractor of responsibility for units excluded from warranty coverage because of accidental damage or "retest O.K." (RTOK) situations -- e.g., one in which a good unit is returned for repairs which are not needed.

For many items of communications and radar, failure definition in the ground environment is not as clear-cut as in avionics. For example, a multi-channel ground radio may continue to be operated under degraded conditions or when only one channel has failed, or a ground intercept radar may be classified as "down" or failed on the basis of a target aircraft's having tested the system. An IFF or ground radar will often operate at decreased range or reduced target conspicuousness but actually be continued in commission. These conditions are more likely to occur at remote sites. As a result of these ground equipment circumstances, failure definition for warranty purposes may be more difficult. In addition, failure-verification procedures to be accomplished before units are returned should receive increased emphasis.

2.4 SUMMARY

This chapter has provided an overview of existing warranty-guarantee plans and a description of several factors in the ground electronic equipment area that merit special consideration for warranty planning. On the basis of this background, Chapter Three provides several alternative approaches for warranty of ground systems.

CHAPTER THREE

WARRANTY CONCEPTS

Wa anty concepts are concerned with the contractual commitments that a suppl..r makes to repair or replace an item in the event of its failure. The warranty is a fixed-price agreement in which the supplier, for a stated amount, agrees to repair or replace all contractually covered failures that occur during the warranty period. Periods of coverage are typically for three to five years, as contrasted with the "standard" warranties, which basically cover only initial defects for a period of one year or less. The standard warranty approach is to return the failed item to the manufacturer for repair or replacement at his option. The standard procedure of returning an item for repair or replacement may not apply to ground systems, because of their size, remote location, or design characteristics. For example, the items may not be transportable, or they may be so heavy that the transportation costs are prohibitive. This chapter reviews several alternative approaches that may be considered for ground system warranties.

3.1 TRADITIONAL MAINTENANCE LEVELS

To place the several warranty concepts in perspective, it is useful to review the traditional maintenance levels employed for Air Force ground electronic equipment. Although the scope of maintenance performed can vary widely within each of these levels, the levels can be described generally as (1) on-equipment, (2) off-equipment, and (3) depot.

3.1.1 On-Equipment

On-equipment maintenance is performed at the installed equipment's location to verify that the equipment has failed and to identify and replace the failed unit. Typically, fault isolation and replacement are performed at high equipment levels (e.g., assembly or subassembly) to permit rapid restoration of the equipment. On-equipment maintenance is also referred to as organizational level maintenance because it is normally the responsibility of and performed by the using organization.

3.1.2 Off-Equipment

Off-equipment maintenance is normally performed at a field repair shop near the installed equipment. Both fixed and mobile repair shops are used. The objective is to fault-isolate major assemblies or subassemblies to the

module or component level. For example, on-equipment maintenance, as noted above, may result in equipment restoration by replacement of a failed assembly. Off-equipment maintenance would then fault-isolate and replace a failed subassembly, module, or component. Repairs requiring extensive test equipment or specialized training would not normally be accomplished at this level. Off-equipment maintenance is often referred to as intermediate-level maintenance. It is normally the responsibility of and is performed by designated maintenance activities in direct support of using organizations.

3.1.3 Depot

Maintenance at the depot level entails complex repairs or extensive overhaul of the equipment. It requires more extensive shop facilities and equipment, and personnel of greater technical skill than other levels of maintenance. Typically, only one or two depot locations are established to support a specific system. Depot maintenance is normally accomplished at fixed repair shops when the equipment is returned to the repair facility. However, for some items of ground equipment maintenance teams are dispatched to the equipment site. This latter case is referred to as mobile depot maintenance.

3.1.4 Overview of Basic Warranty Types

A review of the maintenance levels described in the preceding paragraphs suggests that three basic types of warranty could be developed for ground systems, depending on who is responsible for maintenance at the three different levels:

1. Depot Warranty
2. Depot and Field Support Warranty
3. Depot, Field Support, and On-Equipment Warranty

The characteristics of these warranty concepts are shown in Table 3-1. Subsequent sections will address them in greater detail; however, for comparative purposes a short explanation is provided here.

Under the Depot Warranty concept the Air Force provides on-equipment maintenance. The off-equipment, or intermediate-level, maintenance is also performed by the Air Force, but it is normally limited to verifying that the equipment has failed. The contractor provides depot-level maintenance services under warranty on returned units. In the second case (Depot and Field Support Warranty) the Air Force also performs on-equipment maintenance; however, all other maintenance is performed by the contractor under warranty. Field support is considered synonomous with intermediate-level maintenance. The distinction is that the support provided by the contractor under a Field Support Warranty replaces the maintenance that the Air Force normally performs at the intermediate level. It is expected that the contractor will provide maintenance services to the extent possible at the intermediate level and will limit units returned to the depot to those requiring specialized repair and test facilities or extensive failure analysis. In the third case the contractor is responsible for all maintenance.

Table 3-1. WARRANTY CONCEPTS FOR TRADITIONAL MAINTENANCE LEVELS

Warranty Concept	Equipment Location	Responsibility, Timing, and Extent of Maintenance					
		On-Equipment Level		Off-Equipment Level		Depot Level	
		Timing	Agent	Extent	Agent	Extent	Agent
Depot	Local	Immediate	Air Force	Limited*	Air Force	Full	Contractor
	Remote	Delayed	Air Force	Limited*	Air Force	Full	Contractor
Depot and Field Support	Local	Immediate	Air Force	Full**	Contractor	Limited**	Contractor
	Remote	Delayed	Air Force	Full**	Contractor	Limited**	Contractor
Depot, Field, and On-Equipment	Local	Immediate	Contractor	Full**	Contractor	Limited**	Contractor
	Remote	Delayed	Contractor	Full**	Contractor	Limited**	Contractor

*Under the Depot Warranty, off-equipment maintenance by the Air Force would normally be limited to verifying that a failure had occurred.

**Under this warranty concept it is anticipated that the contractor would, to the extent possible, provide full maintenance services at the intermediate level. Units returned to the depot would be limited to those requiring special repair and test facilities or extensive failure analysis.

Under each concept the manufacturer accepts the warranty under a fixed-price agreement. The agreement remains in effect for a stated calendar time or a prescribed operational time, or a combination of the two. The objective of warranty concepts is to give the contractor an economic incentive to achieve acceptable performance in the field. The obligation for maintenance of the item under a fixed-price agreement provides the basic warranty incentive mechanism.

A variation to each of the three basic warranty types is made if the installed equipment is in a remote location and is operated without maintenance personnel in attendance. In this situation a maintenance team is dispatched from a central location to perform the on-equipment maintenance in much the same way as in existing Mobile Depot Maintenance. The extended outage of a failed equipment may be accommodated by redundant elements of the same equipment or by redundant equipment, or functional coverage may be provided by equipment located at other sites. The period of maintenance delay may vary from a few hours to a few months, depending on the frequency of failure, the amount of redundancy, and the criticality of the system. The introduction of remote-site operations requires that special consideration be given in structuring a warranty program to be applied at any of the three levels.

A more detailed discussion of each of the three concepts with respect to how they would apply to ground systems is presented in Sections 3.2 through 3.4.

3.2 DEPOT WARRANTY

Under the Depot Warranty concept the user operates the item, and in the event of failure the item is returned to the manufacturer for repair or replacement. In effect, the contractor is accomplishing the equivalent of depot-level maintenance for the period of the warranty agreement.

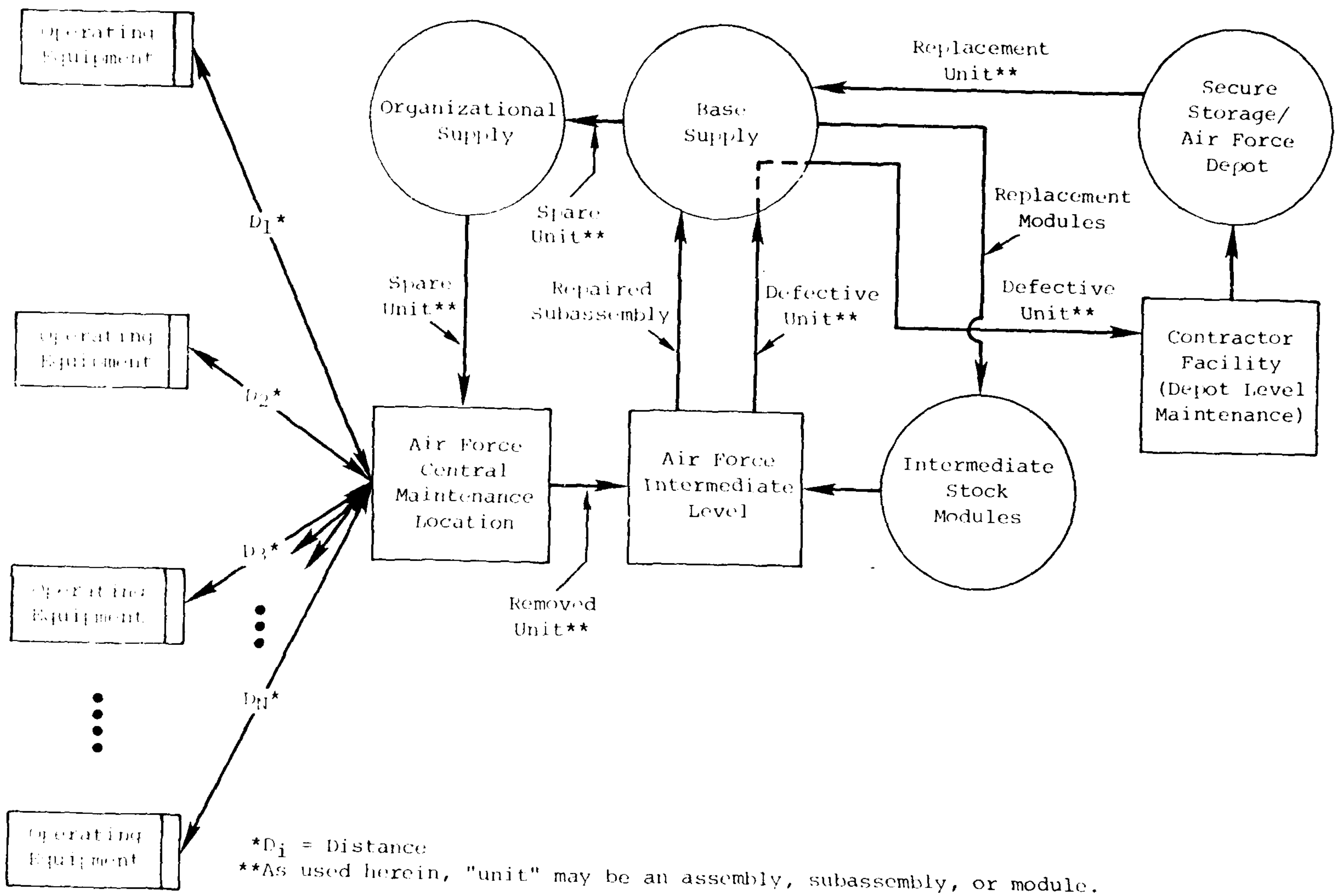
On-equipment maintenance accomplished by Air Force personnel consists of verification that a failure has occurred. In the event the entire unit is not returned, sufficient fault diagnosis must be accomplished to isolate the trouble to a unit level consistent with the level of repair specified -- i.e., subassembly, module, etc. -- for on-equipment maintenance. If the level of equipment returned to the manufacturer is lower than that specified for on-equipment maintenance, the removed unit is passed to intermediate or off-equipment maintenance for further fault isolation to the proper level. In addition to fault isolation and replacement, the on-equipment Air Force personnel are also required to perform designated preventive maintenance, such as cleaning, lubrication, inspection, and replacement of such routine items as light bulbs and fuses.

Off-equipment maintenance for items under warranty normally consists of accomplishing a minimum performance check to verify that a removed item has indeed failed before shipping it to the manufacturer. As noted above, off-equipment maintenance may also be required to fault-isolate to a lower level, i.e., subassembly or module.

Upon receipt of the failed items, the contractor is required under terms of the warranty to repair or replace them. Returned items that have experienced physical damage are typically excluded from warranty coverage. Other exclusions may be authorized if considered appropriate. For example, to preclude unauthorized internal maintenance, the warranted item may be a closed unit with warranty seals attached. A broken seal could constitute an exception to the warranty. Repair of excluded items is normally accomplished under a separate contract on either a time-and-material or fixed-rate basis.

The overall logistics flow for ground systems with depot warranty is presented in Figure 3-1, which depicts a number of equipments located "D" distance away from an Air Force central maintenance facility that provides on-equipment maintenance. In many cases the Air Force maintenance facility will be collocated with the equipment, i.e., D = 0. In other cases the distance could be very small, as in the case of local base maintenance support. In a remote-maintenance concept, the distance could be several hundred miles. In the concept portrayed in Figure 3-1, the Air Force on-equipment maintenance personnel fault-isolate and replace the failed unit. As noted in the figure, the word "unit" can be an assembly, subassembly, or module. If the warranty is at the equipment level of the unit removed, the Air Force intermediate-level maintenance personnel verify the failure and process the defective unit back to the contractor's facility through base supply. However, if, for example, the warranty is at the subassembly level and the removed unit is at the assembly level, additional action must be taken at the intermediate level. It is necessary to remove and replace the faulty subassembly. The repaired assembly is then sent to base supply as a ready-for-issue spare, and the faulty subassembly that was removed is processed back to the contractor's facility through base supply. If a subassembly has been removed and the warranty is at the module level, intermediate-level maintenance personnel remove and replace the module. (A small stock of spare modules is maintained at the intermediate level for this purpose and is replenished by base supply). The repaired subassembly is sent to base supply, and the defective module is returned to the contractor.

The description of level of repair for each level of maintenance is a critical decision and will of course affect the type of spares to be located at the various storage locations. For large ground systems, the return of lower-level assemblies has several advantages, including reduced transportation costs and spares cost. Disadvantages include the possibility of (1) maintenance-induced damage, (2) no-trouble-found, and (3) incomplete information for engineering failure analysis since only a lower-level assembly is returned and its failure might have been caused by another lower-level assembly that is not returned. The selection of the specific level for return will require analysis of these factors to determine the level that is consistent with equipment design considerations, economic concerns, and system availability requirements. The manufacturer's concerns for increased liability due to maintenance-induced failures and transportation damage must also be considered in the analysis.



*D_i = Distance
**As used herein, "unit" may be an assembly, subassembly, or module.

Figure 3-1. LOGISTICS FLOW: DEPOT WARRANTY

As indicated in Figure 3-1, the repair/replacement return concept can be expedited by use of the bonded storeroom concept. In this approach the user, upon confirmation of a field failure, sends a message (through the Air Force Item Manager) to the manufacturer that a failed unit will be returned. The manufacturer will withdraw a user-owned spare item from the bonded storeroom and ship it to the field location. Upon receipt of the failed item, the manufacturer will repair it and place it in the bonded storeroom. A repair turnaround time is normally established to provide control over the repair cycle. Use of the bonded storeroom concept, in association with a repair/replace return warranty, can significantly reduce the number of spare items necessary to achieve a required operational availability.

The manufacturer, through the warranty process, can directly view the results of field operations. Because of the fixed-price arrangement, it is to his advantage to develop modifications that will improve item reliability and reduce the potential for future item failure. The manufacturer is thus encouraged to develop no-cost (to the user) change proposals to improve the item's reliability. The manufacturer's obligation to retrofit all items in the inventory is a negotiated variable.

Depot warranty with remote-site operation is quite similar to the basic Depot warranty. The contractor's obligation is still limited to depot maintenance. However, with remote operation there may be a considerable delay between the time the failure occurs and the time the item is removed for return to the manufacturer. Here it is assumed that there is redundancy in the system and that an item's failure does not require immediate maintenance action. Equipments that use redundancy typically operate in a remote location without maintenance personnel. Such equipment can be monitored remotely to determine if a failure has occurred or can be tested by periodic visits of roving maintenance teams.

Warranty with remote-site operation can be complicated by one or more of the following factors:

- Spares pipeline time is increased because of delay in failure discovery and extra distances involved.
- Failed assets become batched because of the schedule of the remote site team. Batched returns can impede the orderly flow of material through the contractor's repair facility.
- Difficulty is encountered in relating failures to specific circumstances. This can degrade effective failure-circumstance documentation and subsequent failure analysis.
- Unless the equipment is properly instrumented, the exact time of failure may be difficult to identify. Toward the end of the warranty period, it may not be known if the failure actually occurred before warranty expiration.
- Timely installation of reliability- or maintainability-improvement modifications may be difficult in situations where site visits are infrequent.

Depot warranty applications in which the installed equipment will be operated remotely will require careful consideration of these factors, and terms and conditions will have to be adjusted correspondingly to reflect any undue risks.

3.3 DEPOT AND FIELD SUPPORT WARRANTY

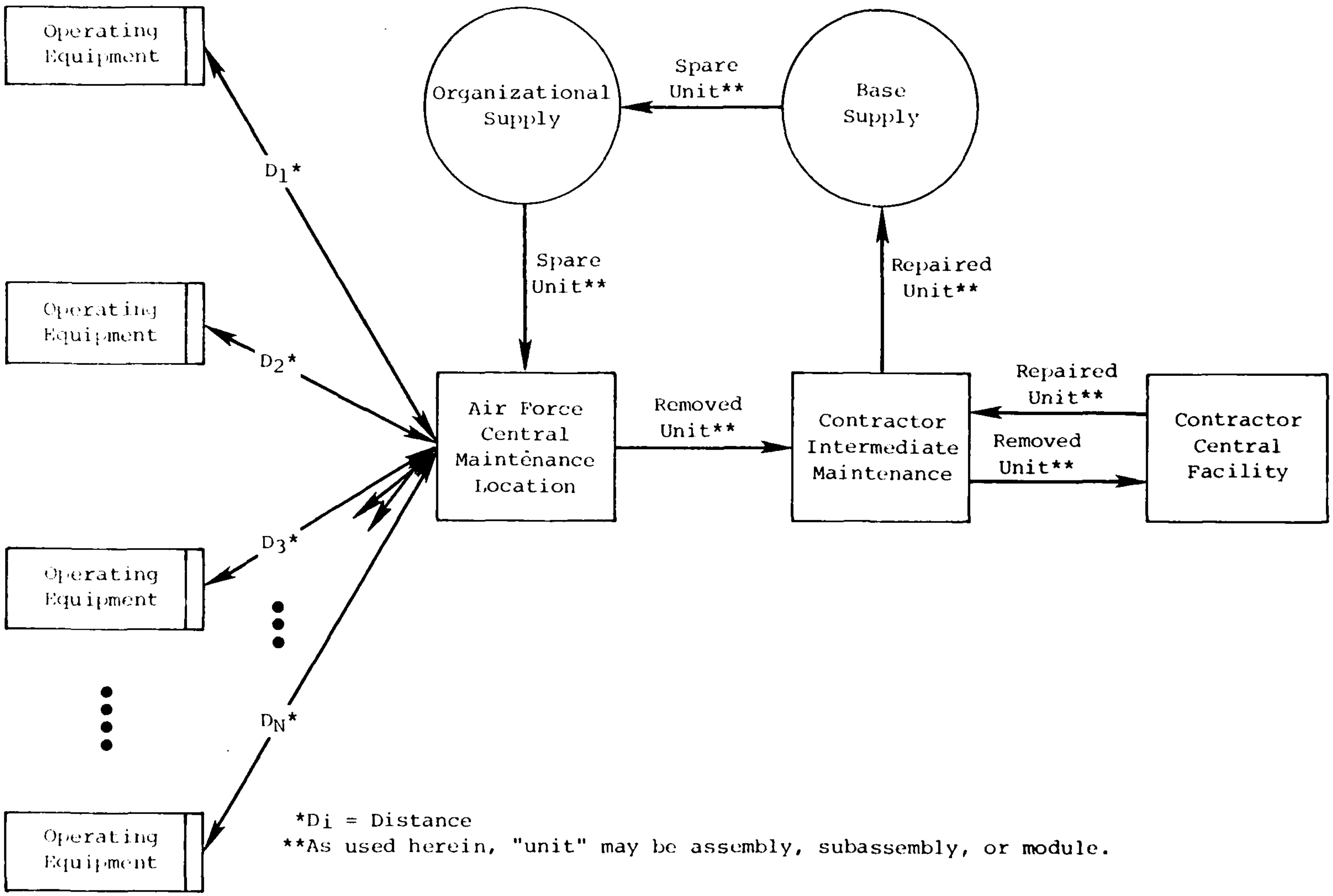
Under the Depot and Field Support warranty concept the contractor supplies not only depot-level maintenance but also field maintenance support at one or more locations. Field support can be collocated at the operational site or at centralized locations that service dispersed operational sites. The Air Force supplies on-equipment maintenance as well as prescribed preventive maintenance.

Extending warranty to include field support is typically of interest where the end equipment has low reliability and the units removed from the equipment are costly or are difficult to transport.

The general logistics flow under this concept is presented in Figure 3-2. On-equipment maintenance is conducted by Air Force maintenance personnel in the same manner as that previously indicated for Depot warranty. However, in this case the contractor provides intermediate-level maintenance for field support. He receives units removed from the equipment operating sites and, within a specified period, repairs the units and returns them to base supply. It is the contractor's responsibility to decide what will be repaired at the intermediate-level site and what will be returned to a central contractor facility comparable to a depot. Transportation costs will be an important factor in the contractor's decision.

Warranty extended to include field support contains many additional factors that must be considered in forming a warranty agreement, including the following:

- Number and location of field support sites
- Assurance that a sufficient work load will be generated at the field location(s)
- Ownership of tools, test equipment, and other maintenance facilities, including space and utilities for field contractor operations.
- Logistics flow and ownership of spare parts
- Control of asset flow from the contractor field support site or depot and return
- Warranty administration at the field support site, particularly a determination of who will perform the normal AFPRO/DCAS warranty-related responsibilites.



*Di = Distance
**As used herein, "unit" may be assembly, subassembly, or module.

Figure 3-2. LOGISTICS FLOW: DEPOT AND FIELD SUPPORT WARRANTY

For Depot and Field Support warranty operated under remote-maintenance conditions, the points mentioned under Depot warranty also apply. To assure that the warranty program provides proper incentive to the contractor, it is important to define carefully the interface between the contractor's field facility and the base maintenance and supply activities. Part of this interface is the specification and control of item-repair turnaround time. In addition, to assure the achievement of desired support characteristics, it may be desirable to couple a Field Support warranty with a selected guarantee -- MTBF, logistics support cost, etc.

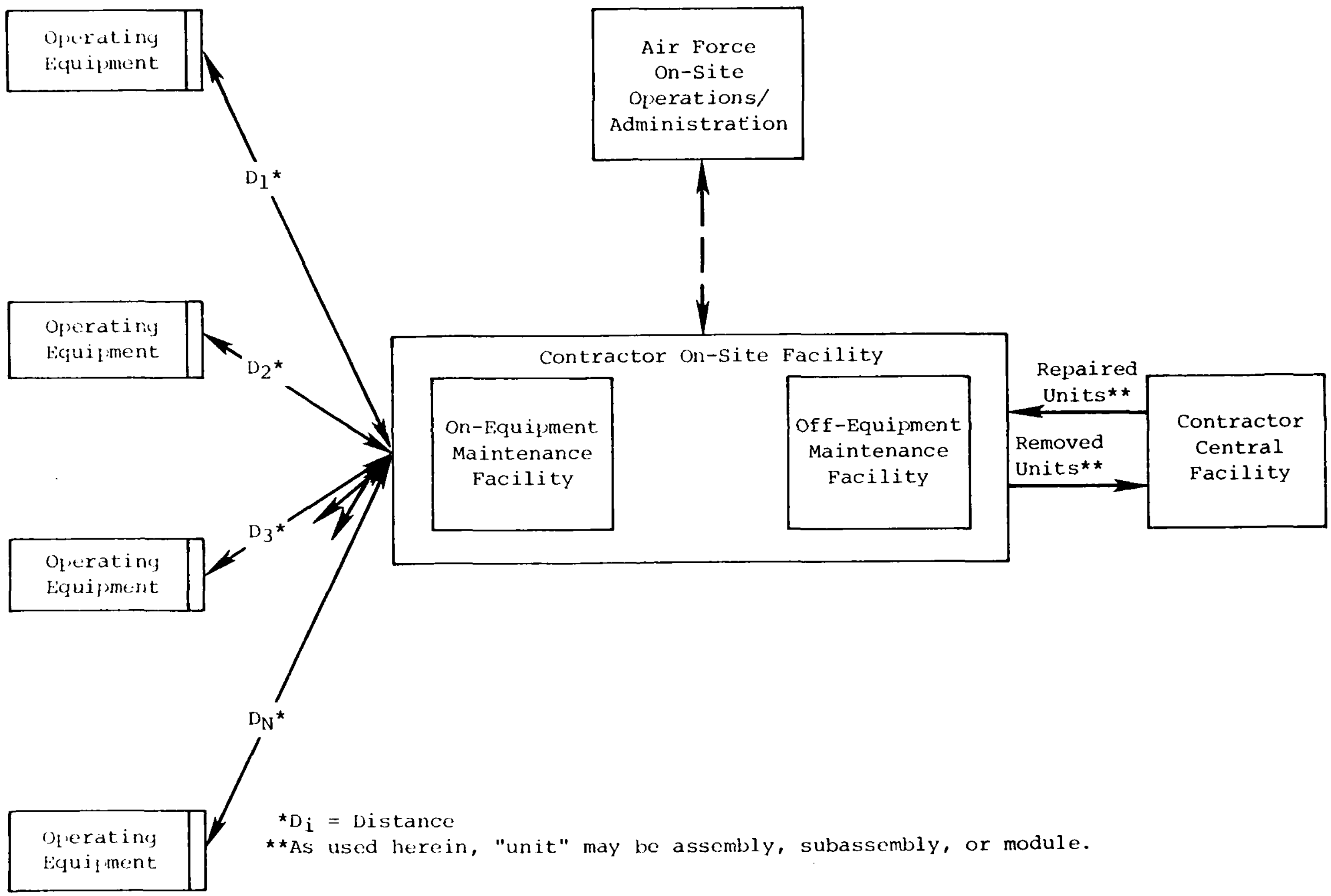
3.4 DEPOT, FIELD SUPPORT, AND ON-EQUIPMENT WARRANTY

Under the Depot, Field Support, and On-Equipment concept, the contractor assumes full responsibility for all maintenance required by the equipment. In addition to depot and field support, the contractor performs the on-equipment maintenance, including corrective and scheduled or preventive maintenance. Reasons for using this type of warranty are similar to those given for the Depot and Field Support warranty. The primary basis for extending warranty to include on-equipment maintenance is highly complex equipment maintenance (corrective or preventive).

The logistics flow under this concept is illustrated in Figure 3-3, which shows that the flow is totally within the contractor's purview. Interface between the Air Force and the contractor occurs primarily on site. The local Air Force operations personnel indicate the need for maintenance and monitor the contractor's activities to restore operations within the prescribed limits.

In some cases the contractor may elect to collocate on-equipment and off-equipment maintenance personnel and facilities, while in other cases, depending on the number of sites, equipment transportability, and other factors, he may elect to have separate locations. The division of maintenance between on-equipment, off-equipment, and a central facility would fall within his purview. In fact, he might choose to eliminate entirely one or more of the specific maintenance levels. Such action is permissible if the contractor can meet the prescribed maintenance performance criteria. The definition of maintenance restoral times, availability, or other service parameters is the key to giving the contractor the proper incentive. To ensure that the desired parameters are met, the warranty can be coupled with an appropriate guarantee.

This concept may also be extended to remote equipment operation. Here the contractor has complete maintenance responsibility but, instead of locating his personnel at fixed sites to perform on-equipment maintenance, he is committed to providing maintenance support of remote sites on a demand or scheduled basis. Since the contractor will not be resident at the remote location, the warranty agreement must specify reasonable criteria governing the allowable time for restoration of a failed item. These criteria must take into account the method of failure detection, i.e., remote sensing or [illegible] inspection. As in the Depot warranty concept, for remote



*D_i = Distance
**As used herein, "unit" may be assembly, subassembly, or module.

Figure 3-3. LOGISTICS FLOW: DEPOT, FIELD SUPPORT, AND ON-EQUIPMENT WARRANTY

maintenance to be possible, there must be a means of providing operational coverage in the event of a failure.

Application of this concept requires making a number of key decisions concerning the following:

1. Commitments for equipment operational goals in terms of availability, operating hours per designated period, or other applicable parameters
2. Provision of tools, test equipment, maintenance facilities, and shop space at all maintenance levels
3. Ownership and flow of logistic assets at all maintenance levels
4. Reimbursement for transportation costs
5. Methods for notifying the contractor of the need for maintenance
6. Method to assure that the contractor has performed the required preventive maintenance
7. Remedies in the event the contractor does not meet operational goals

The potential complexity of the Depot, Field Support, and On-Equipment concept, dictates that considerable lead time be provided prior to the request-for-proposal date to assure that a complete and realistic warranty program is developed.

3.5 SUMMARY

This chapter has reviewed various alternatives that might be considered for ground system warranty. The concepts discussed take into account the fact that some ground systems are highly complex, exist in small quantities, and are difficult to transport. Warranty concepts that provide for contractor-supplied field support or on-equipment maintenance may be found to be cost-effective for some of these situations. In addition, it should be recognized that in some situations the concepts can be applied to selected sites while Air Force maintenance is retained at other sites. Benefits gained from the contractor-maintained sites -- for example, early identification of pattern failures, inadequate procedures in technical manuals -- would be transferable to the sites maintained by Air Force personnel.

Recent trends in the reliability of electronic equipment may also have an impact on the use of the warranty concepts discussed. For example, Subsection 2.3.3.6 in Chapter Two indicated that some items of equipment being procured today demonstrate extremely high MTBFs and that there may be little opportunity for reliability improvement. However, there may still be the opportunity to improve equipment availability through maintainability improvements, or to reduce manning requirements through effective use of contractor maintenance coupled with warranty concepts. Subsequent chapters of this report will examine in more detail the process for

structuring a specific warranty concept and for evaluating its economic viability. In addition, guarantees of various types may be a useful adjunct to a warranty program. Chapter Four addresses possible guarantee concepts and their use independently of, or in conjunction with, the warranty concepts discussed in this chapter.

CHAPTER FOUR

GUARANTEE CONCEPTS AND PLANS

The warranty concepts discussed in Chapter Three identified alternatives whereby the contractor would be contractually responsible for certain maintenance activities on equipment he has produced.

In this chapter the uses and limitations of guarantees for ground electronics equipment are examined. The relationship between a warranty and guarantee is also explained, and examples of military uses of guarantees are presented. This chapter also describes several types of guarantees for ground equipment and identifies the goals and control parameters for each guarantee and the impact of the guarantee on an equipment's operations and support activities. The potential impact of a guarantee on other acquisition-program features is examined together with types of remedies that can be used.

4.1 THE GUARANTEE CONCEPT

4.1.1 The Meaning and Use of a Guarantee

As used in this report, a *guarantee* is a commitment by the seller to the Government that the equipment will achieve specified field operational goals. Through a guarantee, the contractor and Government recognize that certain equipment characteristics cannot be adequately determined by normal inspection and acceptance procedures. The guarantee permits the Government to determine the equipment's conformity with certain requirements when the equipment is in an operational environment. If the equipment fails to meet these requirements, the guarantee will identify the consideration that will be provided by the contractor or any other remedies available to the Government.

4.1.2 The Relationship Between Warranty and Guarantee

In many procurements, the incentives provided by a warranty alone may be neither sufficient nor proper to achieve specific operational capabilities. An example of such a situation is provided in the following paragraph.

Assume that a contractor, under warranty, is responsible for all depot-level maintenance for a specific equipment. Assume also that the equipment MTBF is less than expected and that the frequency of repairs exceeds that

used by the contractor to establish his warranty price. The contractor could decide, on a purely economic basis, to ignore development of no-cost ECPs or other modifications for the equipment and simply make the necessary repairs by the most economical means available. From the contractor's view, this decision can be most cost-effective, even if it means a reduced profit or eventually a loss on the warranty line item of the contract. If the contractor makes this choice, the Government's depot maintenance costs are fixed for the duration of the warranty period; however, the Government will incur higher maintenance costs at the organizational and intermediate maintenance levels because of the increased number of failures. In addition, the Government may have to buy additional spares to maintain the supply pipeline. Finally, when the Government does take over the depot maintenance, its costs will be greater because the MTBF is less than specified.

Therefore, without regard to any responsibility or obligation associated with warranty, it may be beneficial for the Government to require a contractor to guarantee specific control parameters -- MTBF in the example given. In the event his guarantee is not met, the contractor incurs specific responsibilities that are independent of other contractual requirements.

Thus, while a warranty and a guarantee may be used to provide complementary incentives on a contract, each concept has unique features and each provides a different [illegible] for the incentive process.

4.1.3 Requirements for a Guarantee

The basic elements of a guarantee are as follows:

- Identification of the equipment. Includes not only the nomenclature of the equipment but also the [illegible] or quantities involved.
- Duration of guarantee. Identifies the specific period (e.g., calendar time, operating time, or operating hours) over which the guarantee is in force.
- Characteristics to be guaranteed. Includes not only identification of the control parameters (e.g., reliability and a tabulation or schedule of guaranteed values) but also the units of measurement (e.g., MTBF in hours) and the method and frequency of determining compliance.
- Notification of noncompliance. Includes Government procedures for notification of noncompliance and the schedule for such notification.
- Other obligations of the parties. Includes specific contractor or Government responsibilities associated with implementation and administration of the guarantee (e.g., data collection and verification responsibilities).
- Remedies for guarantees not met. Describes both the nature of the remedy and the schedule for compliance in the event that guaranteed values are not met.

The details of each guarantee must be tailored to the procurement for which the guarantee is considered.

4.2 MILITARY USE OF GUARANTEES

Table 4-1 summarizes the major features of several guarantees that have been used in recent DoD procurements. These programs are discussed in the following subsections.

4.2.1 MTBF Guarantee

The MTBF guarantee was pioneered and developed by the commercial airlines; it has been adapted by DoD for the procurement of military avionics. It is often used to complement a reliability-improvement warranty (RIW), which requires the manufacturer to be responsible (at a fixed price) for depot-level repairs of his equipment.

In an MTBF guarantee the contractor guarantees that a stated mean time between failures (MTBF) will be met or exceeded by his equipment when it is used in a military operating environment. If the equipment fails to meet guaranteed MTBF values, the guarantee requires that the contractor agree to institute corrective action and to provide consignment spares to the military until the MTBF improves to preestablished values. The contract may also require that if at the end of the guarantee period the required MTBF is not met, all or a portion of the consignment spares become Government property at no increase in contract price.

For the TACAN and F-16 procurements shown in Table 4-1, the MTBF guarantee complements an RIW requirement. Thus the RIW provides an indirect incentive for achieving MTBF through the contractor's maintenance commitment. The MTBF guarantee provides a direct MTBF incentive because of the consignment-spares requirement. Through the MTBF guarantee, the Government, although never assured of achieving the required MTBF, has additional protection against pipeline spare shortages that can develop if the equipment has low MTBF.

Hence, in addition to any incentives due to warranty, the guarantee provides specific incentives for the contractor and improved protection for the Government in the event that guaranteed values are not met.

4.2.2 Availability Guarantee

The airline industry has made some use of dispatch reliability, which is a limited form of availability control, but to date very few attempts have been made in DoD to implement any sort of availability guarantee. The two major reasons for this are (1) difficulty in defining availability in contractual terms and then being able to measure it with enough accuracy to verify contractual compliance or noncompliance, and (2) accounting for the fact that for many equipments at least some of the support factors that influence availability are outside the contractor's control.

Table 4-1. SUMMARY OF RECENT DOD GUARANTEE PROGRAMS

Equipment/Manufacturer	Type of Guarantee	Control Parameter	Duration	Remedy	Results to Date	Comments
AN/ARN-118 TACAN Collins	MTBF	MTBF, operational value is estimated at six month intervals. Schedule of increasing values ranging from [illegible] to [illegible] hours.	Varies with each of several production lots. Minimum period is 2 years.	Contractor supplies (a) consignment spares at no cost to Government (exact number related to achieved MTBF); (b) engineering investigation to identify cause of low MTBF; (c) modifications as required, to produce conforming equipment.	Guaranteed MTBF values exceeded in each measurement period.	Contractor repairs all failures under warranty.
F-16 Avionics Systems: Fire control Radar Transmitter Westinghouse; Head-Up Display [illegible] Electronics/Marconi	MTBF	Same as above.	Four years or up to [illegible],000 flying hours by a specified number of U.S. and foreign aircraft.	Same as above.	No operational results to date. First assessment period expected to occur in early 1980.	General Dynamics, prime contractor for the aircraft, has both warranty and guarantee on these items. An additional 7 items have warranty only.
T-34C Cockpit Procedure Trainer [illegible]	Availability	Operational availability of equipment guaranteed to be at least 96 percent.	One year, with option for additional two years.	Price paid for maintenance services reduced depending on availability achieved.	Availability at or near 100 percent in each measurement period.	Contractor has full maintenance responsibility.
AN/ARC-164 Radio Magnavox	LCC Verification	A life-cycle cost verification test was used to develop data for an agreed-upon LCC model. The resulting LCC estimate was compared with estimates developed prior to contract award.	One-time test; 100 radios were tracked until [illegible],000 hours of operating time were accumulated.	Face value of contract adjusted upward or downward depending on ratio of achieved LCC to bid LCC.	Agreed-to MTBF was exceeded but other cost drivers resulted in an LCC value that precluded any adjustement in contract price.	Maintenance performed by designated Air Force personnel. Minimum direct involvement by contractor.
F-16/General Dynamics	Logistics Support Cost (LSC)	Total LSC for F-16 subsystems not subject to warranty (engines excluded).	Test of 3,500 flying hours on first operational squadron.	Award fee if actual costs are lower than predicted. Material, spares, and engineering support can be required if prediction is exceeded by 25 percent.	None. First assessment expected in 1980-1981 period.	None.

One DoD program that is using an availability guarantee is a Navy procurement for contractor maintenance on cockpit-procedure trainers (these are ground simulators used in training Naval aviators). Because simulator downtime would have an adverse impact on the overall class training schedule, the Navy wanted to give the maintenance contractor an incentive to achieve maximum availability of the equipment during the scheduled training periods. An availability percentage of 96 percent was agreed upon, with availability defined as the ratio of hours during a scheduled period when the trainers were operationally available to trainer hours scheduled during the same period. For example, if the schedule called for 400 hours of training during a period and the trainer was operationally available during only 360 hours of the scheduled period, the availability would be 90 percent. Under the terms of the contract, if the 96 percent guaranteed figure is met, there is no change in the contract price. However, if the guaranteed figure is not met, the price paid for the maintenance services provided is reduced in accordance with a preestablished contractual formula. Alternatively, if the 96 percent figure is exceeded, the contract price is adjusted upward, again in accordance with a preestablished formula. While this contractual arrangement cannot provide the Navy complete assurance that their availability needs will be met, the guarantee provisions, with associated monetary penalties and rewards, does provide a strong incentive to the contractor. Results during the first period of contractual coverage under the guarantee arrangement were sufficiently successful that an option was exercised for continued contractor maintenance during a subsequent period. (In fact, during the first year the availability was at or near 100 percent in each measurement period).

The foregoing example is the only DoD contract identified during the course of this study effort that incorporated an availability guarantee coupled with contractual monetary incentives. However, a Navy/Air Force program, the Joint Cruise Missile Project, is currently evaluating the feasibility of applying an availability guarantee to certain systems of the Air Launched Cruise Missile (ALCM). The results of the evaluation and the details of the concept, if implemented, will not be available for some time. However, the evaluation does indicate a willingness on the part of DoD to consider availability guarantee arrangements even on major programs such as the ALCM. Additional aspects of availability guarantees for ground equipment are discussed in Section 4.3.3.

4.2.3 Cost Guarantee

The cost guarantee can take several forms depending on the specific costs of interest. Table 4-1 gives examples of Life-Cycle Cost (LCC), and Logistics-Support Cost (LSC) guarantees. In either case, agreement is reached on an appropriate cost model that combines individually estimated parameters to arrive at a total "predicted cost". The contractor guarantees that the cost to operate his equipment will be no more than this guaranteed amount. A field test is conducted to obtain estimates for the principal variables in the cost model (e.g., MTBF, MTTR, and average repair cost). The resulting "actual estimate" is then compared with the guaranteed value to determine compliance.

The AN/ARC-164 UHF Radio procurement, as indicated in Table 4-1, went far beyond the consideration of life-cycle cost as a source-selection factor. This contract required that a sophisticated LCC verification test be run to obtain "actual LCC" estimates. These estimates were compared with "predicted LCC" estimates developed prior to award of the production contract. The results of this comparison were used to determine whether the contractor would receive an incentive reward or a penalty. This arrangement had all the elements of a guarantee in which life-cycle cost is the controlling parameter. A great deal of effort went into developing both the model and the verification test plan and procedures for this program. At the conclusion of the test, although the agreed-to MTBF had been exceeded, other cost drivers resulted in an LCC value that precluded adjusting the contract price either upward or downward. If future effort could better identify LCC drivers and then reflect these findings in a simpler LCC "model", the administrative effort associated with such guarantees could be greatly reduced.

The General Dynamics F-16 contract requires that a similar demonstration be performed under its Logistics Support Cost (LSC) commitment. Certain data will be collected on the first operational squadron of F-16s during a test that will last for 3,500 flying hours. Again, as with the AN/ARC-164, operational estimates of logistics and support factors will be fed into an LSC model and the "actual" results will be compared with "predicted" estimates developed prior to source selection.

If "actual" LSC is less than the "predicted", General Dynamics (GD) is eligible for an award fee. If the "actual" LSC exceeds the "predicted" by more than 25 percent, certain remedies are available to the Air Force. The possible remedies include having GD provide assets, engineering investigations, and modifications.

In each of the cost guarantees discussed in this section, there is no contractor warranty and all repairs are expected to be made by service personnel. With the AN/ARC-164, however, Magnavox and the Air Force did agree that only "designated" personnel would be allowed to perform maintenance actions that contributed data to the LCC verification test. This agreement allowed the contractor to have confidence in the actual skill levels that were being brought to the maintenance task.

4.3 APPLICATION TO GROUND ELECTRONIC SYSTEMS

The guarantees discussed in Section 4.2 were developed primarily for avionics or aircraft-related systems. The parameters that they address and the controls that they impose are basic enough to apply to many ground systems. On the other hand, the diversity of ground equipment deployment and use permits not only additional forms of guarantee but also variations on those concepts already used for avionics. This section addresses the choices available for ground system guarantees, the specific controls that each choice promotes, and the implementation and administrative impacts of these alternatives.

Four classes of guarantee are identified for ground systems. Specific examples of three of the classes were discussed in Section 4.2: reliability, availability, and cost guarantees. The fourth class, the maintainability guarantee, has not been previously discussed but will be covered in Section 4.3.2. The major features of each class are summarized in Table 4-2.

Table 4-2. CLASSES OF GUARANTEES FOR ELECTRONIC EQUIPMENT

Type of Guarantee	Goal	Control Parameters
Reliability	Control frequency of failure or maintenance events.	MTBF MTBMA (maintenance actions) MTBSF (system failures)
Maintainability	Control the statistics of the maintenance distribution. Can address both corrective and preventive maintenance.	MTTR Percentile control on corrective maintenance times Mean PM time Percentile control on preventive maintenance times Mean man-hours to repair
Availability	Control rate of use that can be achieved. Conversely, control outage rate or downtime rate.	Operating hours per month System downtime per month
Cost	Control mix of dollar and other resources needed to buy, operate, and support a system.	Can be dollars or a dimensionless ratio

4.3.1 Reliability Guarantee

4.3.1.1 Description

The MTBF guarantee is a specific member of the reliability class and is used to motivate the contractor to reduce either the frequency of failures in a system (as defined for each system) or the frequency of maintenance events associated with a system. The latter alternative recognizes that in redundant or fail-soft systems, maintenance activity may not be directly relatable to system failures. This situation occurs infrequently in avionics systems because weight, volume, and power constraints often lead to nonredundant designs in which a single failure is often synonomous with system failure.

Variations in a reliability guarantee are made when the guarantee is adapted to meet the definition of "failure" for a system. Thus the control parameter can be any measure of the usage available between specific classes of failure maintenance events, for example:

MTBF - mean time between failures

MTBMA - mean time between maintenance actions

MTBSF - mean time between system failures

4.3.1.2 Implementation Requirements

DoD experience in developing and administering MTBF guarantees has indicated that the critical implementation features of a reliability guarantee are related to the following:

- Definition of failure or maintenance event. Can they be defined at the time an offeror must sign a contract? What exclusions, if any, are permitted, and to what extent will no-trouble-found events be counted as failures? Who will verify the system failure?
- Estimating usage. How will the population usage be established over the guarantee interval? Can it be measured directly or must it be estimated? What are the sources of errors in collecting usage data? Must all equipment usage be measured, or will sampling techniques produce adequate usage estimates?

Once these features are established and agreed upon, the basis of a reliability guarantee will be well founded.

4.3.2 Maintainability Guarantee

4.3.2.1 Description

The maintainability guarantee has not been used (as a "stand alone" requirement) in any known DoD procurements. Maintenance data have been collected and certain parameters estimated as part of cost guarantees, but these actions were small parts of a larger estimation effort. In a maintenance guarantee the control parameter is related to either the average time required to restore a system to operation after failure (MTTR) or other features of the repair time distribution (preventive control), or to the resources required to make a repair (mean man-hours per repair). Combinations of these parameters may be used; if desired, the distribution of preventive maintenance (PM) times may also be addressed in the control parameter.

The area of maintenance guarantees has not been well developed in the aircraft community, because in-flight repair is rarely planned for most systems [illegible]. In addition, maintenance times on aircraft are more often related to system location and accessibility, which are under the airframe manufacturer's control, than to specific inherent design characteristics. Since ground systems have quite different usage and deployment

environments, they can provide greater opportunities for developing the maintainability guarantee concept.

The maintainability guarantee can address either the system downtime during failure or the manpower resources required to repair a failure. It will not control the total manpower requirements for maintenance since it does not address the frequency of repair for the system.

4.3.2.2 Implementation Requirements

Like the definition of failure for a reliability guarantee, the definition of maintenance time is a critical feature of the maintenance guarantee. What elements of the maintenance activity are chargeable to the total time? What assumptions are understood with respect to spares, manuals, training, tools, maintenance technician skill levels, etc.?

It is also important to identify the maintenance activities that will be measured to establish conformance. What maintenance events are not to be counted (e.g., lightning that causes extensive equipment damage, power transients that are not the offeror's responsibility, negligence, etc.)?

Finally, who will record and validate the data? This aspect will be extremely important if the contractor is not at a facility at least to witness the repair activity.

4.3.3 Availability Guarantee

4.3.3.1 Description

The availability guarantee combines many features of the reliability and maintainability guarantees. Now the control parameter is the operability or utility (per unit of time) of the subject equipment or, equivalently, a limit on the downtime or nonoperability of the equipment per unit time.

The control parameter for an availability guarantee may have one of the following forms:

- Operating hours per month
- Maintenance time per month
- System downtime per month
- Maximum downtime per failure
- Percent of shifts completed without failure
- Average maintenance time per shift

For items used periodically the control parameter may be:

- Percent of exercises completed without failure
- Average maintenance time per exercise

4.3.3.2 Implementation Requirements

As indicated in Section 4.2.2, two major difficulties in implementing an availability guarantee are (1) defining availability in contractual terms and then measuring it with enough accuracy to verify contractual compliance or noncompliance, and (2) accounting for the fact that for many equipments at least some of the support factors that influence availability are outside the contractor's control. Therefore, implementation of the availability guarantee will first require a careful definition of the term itself. It may be that for some applications availability can be defined by using the traditional approach of combining both reliability and maintainability factors. However, in many situations, using this definition approach will result in extreme difficulty with contractual measurements. Alternative definitions of availability, using one of the parameters cited above, should ease the measurement problem.

The Navy procurement on cockpit-procedure trainers cited in Section 4.2.2 indicated how availability can be defined to meet the special circumstances of individual equipments and the specific Government objectives. The measured availability could also be based on special tests. For example, one approach being considered on the Air Launched Cruise Missile is to estimate the availability by using a combination of ground tests conducted with test equipment and actual operational test launches. The conditions under which the tests are conducted would be spelled out in test plans and agreed to by both the manufacturer and the Government.

Another major consideration in implementing an availability guarantee is the degree of control the contractor has over the various support factors that could affect availability. For example, if the contract provides that Air Force maintenance technicians perform some or all of the preventive maintenance required, what skill levels will be required of technicians who will complete the tasks? If the contractor performs the maintenance and the Air Force provides replacement parts, what stock levels will be maintained? Approaches to addressing implementation requirements for an availability guarantee are discussed in Chapter Seven, which discusses contractual warranty-guarantee provisions.

4.3.4 Cost Guarantee

4.3.4.1 Description

The examples in Section 4.2.3 illustrated the basic features of a cost guarantee. The control parameter is defined by a model that combines a number of cost, maintenance, or other support parameters. By proper selection and tailoring of a model, one can emphasize the important parameters associated with the purchase, operation, and support of a system. In Table 4-1, the units of the cost-guarantee control parameters were dollars. But this need not be the case. One could establish the control parameter as the ratio of measured cost to predicted cost. In this case the control parameter is dimensionless.

4.3.4.2 Implementation Requirements

The complexity of the cost model will determine the implementation effort associated with a cost guarantee. If it is necessary to estimate reliability and maintainability parameters, all of the implementation problems associated with reliability and maintainability guarantees must be addressed. If additional parameters such as spare parts cost, condemnation rates, no-trouble-found ratios, etc., must be estimated, then a test plan and procedures must be developed to clearly identify responsibilities and procedures for collecting such data.

The effort to implement a cost guarantee can be reduced by limiting the number of independent variables in the model. For example, let

$$Z = \frac{A}{MTBF} + B(MTTR) + C \text{ (average repair cost)} \tag{4-1}$$

Prior to contract award, regions of interest for MTBF, MTTR, and average repair cost can be identified for the system in question. Equation 4-1 can be correlated with a more extensive LCC model over the region of interest to establish best-fit estimates for A, B, and C. Then, in a verification test, Equation 4-1 can be used as a control parameter.

While this approach allows a contractor to "game" LCC parameters that do not appear in Equation 4-1, it does provide an alternative to developing complex verification test plans and procedures.

4.4 IMPACT ON DESIGN AND SUPPORT ELEMENTS

It was stated earlier that a guarantee can provide a contractor with an incentive to meet control-parameter values. If the guarantee requirement is introduced into a program early enough (certainly no later than design freeze and perhaps as early as FSED contract award), a contractor has the opportunity to modify his equipment design so as to increase his likelihood of meeting any guaranteed parameter. Even in other cases where the equipment is to a large degree commercially available or is a military adaptation of a commercial item, the manufacturer still has the opportunity to make changes which would have a favorable impact on some of the guaranteed parameters. Table 4-3 examines several design and support program elements that could be affected by various guarantees.

The reliability and maintainability guarantees act in mutually exclusive areas, reflecting the difference in emphasis between these incentives. On the other hand, availability and cost guarantees have the potential to affect all areas, to the extent that the guarantee parameters are influenced by these areas.

In summary, as the nature of the guarantee becomes more complex, it appears that the guarantee has more opportunity to affect various design and support activities.

Table 4-3. POTENTIAL FOR GUARANTEE IMPACT ON DESIGN AND SUPPORT PROGRAM				
Program Elements Affected	Reliability Guarantee	Maintainability Guarantee	Availability Guarantee*	Cost Guarantee*
Design Program				
Reliability	X		X	X
Maintainability		X	X	X
Redundancy	X	X	X	X
Modularity		X	X	X
Built-In Test		X	X	X
Support Program				
Manuals		X	X	X
Training		X	X	X
Test Equipment		X	X	X
Tools		X	X	X
Sparing Levels	X	X	X	X
Manning Levels	X	X	X	X
*Emphasis will depend on specifics of guarantee.				

4.5 REMEDIES

The remedies available to the Government in the event of contractor failure to meet guaranteed values are the most important part of a guarantee. Without a clear statement of remedies, the remainder of the guarantee can carry little impact or incentive. Historically, three forms of remedy appear in a guarantee: money, services, and material. Each is discussed in this section.

4.5.1 Money

A guarantee can incorporate a payment schedule (or a payment adjustment schedule) as a remedy. Thus if the guarantee is not met, the Government is due some payment or monetary consideration from the contractor. On the other hand, if the guarantee value is exceeded, the contractor may be entitled to additional monetary consideration. The AN/ARC-164 UHF Radio and F-16 LSC guarantees and the Navy Trainer availability guarantee all have some of these features.

4.5.1.1 Impact of Money Remedy on Seller

Additional payments for meeting or exceeding guaranteed values could represent additional profits on this portion of the contract. On the other hand, these payments may only return money that was invested by the seller during the hardware production and deployment efforts in order to meet the guarantee requirements. Thus, even when a guarantee value is exceeded, one cannot be sure that additional payments represent additional profit on the contract.

If the guarantee is not met and the seller is required either to make direct payments to the Government or to reduce previously negotiated prices according to a pre-established schedule, there are at least three possible levels of impact on the contractor:

(1) The payment reduces or eliminates the profit associated with the guarantee line item.

(2) The payment, in addition to (1), reduces or eliminates the profit associated with the contract.

(3) In addition to (2), the payment prevents recovery of some of the seller's costs on the contract.

These are, of course, increasingly serious levels of payment for the seller.

4.5.1.2 Impact of Money Remedy on Government

If additional payments for meeting or exceeding guaranteed values are required, these must be budgeted in advance in order to be available at the proper time. In this case the Government appears to pay a premium to obtain the guaranteed performance. However, this premium is offset by the additional capability of the system or by a reduction in the life-cycle cost of the system.

On the other hand, if the Government receives a payment after a contractor's failure to meet a guarantee, the funds may be considered as:

(1) An offsetting payment for increased LCC of the system

(2) The means to purchase additional manpower or assets to support the system or increase its capability

(3) A simple penalty for failure to perform

As even this brief analysis indicates, the parties that negotiate a money remedy have very different interpretations of the resulting payment schedule.

4.5.2 Services

Instead of monetary consideration for failing to meet a guarantee, a contract could require the seller to provide certain services. For example, an Army contract containing a warranty with an MTBF guarantee requires

the seller to extend the warranty period if the guaranteed value is not met. In other cases, such as the TACAN reliability guarantee listed in Table 4-1, the seller must provide engineering services to investigate the reasons for low MTBF and then develop ECPs and modification kits. Other types of services could also be provided depending on the equipment and the type of guarantee plan used. For example, if an availability or maintainability guarantee is not met, engineering analysis might be required to determine the cause or causes of nonconformance. Several individual factors or a combination of factors could be identified as the cause. For example, if it were determined that technical orders were erroneous and test equipment inadequate, additional services could be required to correct conditions causing noncompliance with the guarantee.

4.5.2.1 Impact of Services Remedy on Seller

The seller's position can be analyzed by converting, for each value of the control variable achieved under the guarantee, the expected amount of services (and modifications) to an equivalent selling price. Then this remedy can be analyzed in terms of a monetary payment. Some uncertainty is introduced in this analysis: the seller may have difficulty estimating his total obligation under this remedy until he has the data showing that he has not met his guarantee. For example, it is difficult to estimate how much it takes to improve a system reliability from 400 to 500 hours' MTBF until the failure modes of the 400-hour system are known.

4.5.2.2 Impact of Services Remedy on Government

The Government's intention under the services remedy is clear. It plans to substitute services for the deficiency in the guaranteed parameter. If the services are well defined, as in the case of a warranty extension, the value of the guarantee, for each achieved value, can be determined in a straightforward manner.

4.5.3 Material

Contracts with MTBF guarantees often require the contractor to provide consignment spares when the guarantee schedule is not met. Similar requirements can be developed for other guarantees. For example, a maintainability guarantee could require remedies such as tool redesign, revision to technical manuals, or improved BITE. For the MTBF guarantee, consignment spares may be required in addition to modification kits that will bring the reliability up to guarantee values.

4.5.3.1 Impact of Material Remedy on Seller

The seller's position can be analyzed by estimating, for various achieved values of the control variable, the cost of the penalty invoked for these achieved values. For example, the expected number of consignment spares (or modification kits) could be computed under different achieved MTBFs and then converted to an equivalent cost. The cost estimate of spares may depend on the timing of the delivery (e.g., is the seller in or out

of production when the spares are due?). The seller may also have difficulty estimating his total obligation for modification kits since the nature of these kits will probably depend on the failure modes of the systems.

4.5.3.2 Impact of Material Remedy on Government

Under the material remedy the Government can choose to increase the number of items in the inventory (through consignment spares) to offset the logistic impacts of low reliability. On the other hand, the modification requirements provide the Government with an opportunity to have the equipment brought up to guaranteed levels.

The modification kit approach has not been implemented under existing contracts; thus the administrative details of this approach are not clear.

4.6 SUMMARY

This chapter has discussed the meaning of a guarantee and the relationship between warranty and guarantee. It was noted that while each concept has unique features and a different focus for the incentive process, the two may be used together to provide complementary incentives. Major features of guarantees were cited in relation to their use on several recent DoD procurements.

The four classes of guarantees identified for potential application to ground electronic systems were reliability, availability, cost, and maintainability. Implementation requirements of each class were discussed. The most important part of a guarantee is the remedy available to the Government in the event the contractor fails to meet the guaranteed values. Three remedies (money, services, and material) were discussed in terms of their potential impact to both the seller and the Government. It was noted that without a clear statement of remedies the guarantee has little impact and offers little incentive.

Each of the guarantees presented in this chapter can be used as a "stand alone" requirement or in combination with a warranty. Contractual provisions applicable to those warranty-guarantee plans are discussed in Chapter Seven. However, before considering contractual provisions for the plans, it is necessary to describe the criteria for their application. These descriptions are presented in Chapter Five.

CHAPTER FIVE

WARRANTY-GUARANTEE APPLICATION CRITERIA

In Chapters Three and Four a variety of warranty-guarantee concepts that could be applied to ground electronic equipment were discussed. However, these concepts are not equally applicable to every procurement. To assist potential users in discriminating between warranty-guarantee alternatives and in identifying the alternatives most likely to offer significant benefits, a number of warranty application criteria have been developed.

5.1 OVERVIEW OF APPLICATION CRITERIA

The proper development of warranty-guarantee provisions requires a great deal of effort on the Government's part to develop procurement, administration, and logistics implementation. Thus the decision to include warranty-guarantee in a procurement should not be made lightly. Table 5-1 presents a number of warranty-guarantee application criteria that can be used to aid in the selection of a warranty-guarantee approach for a specific application. These criteria are generally qualitative and can indicate the general feasibility of a specific warranty-guarantee application. The table is not presented as a simple checklist that can be used alone in deciding on the applicability of a warranty-guarantee. Its effective use requires an understanding of the concepts presented in Chapters Three and Four. The comments provided in the following paragraphs should assist in using the table.

The criteria are arranged by factors into five areas: procurement, equipment, operational, support, and economic. The importance, impact, or implications of each criterion are defined as succinctly as possible. Each user of the table will have to determine the relative importance or applicability of the criteria for his intended use. The other table headings identify the major warranty-guarantee plans that have been identified for ground systems. These include warranty at three levels of contractor responsibility: depot only; depot and field maintenance; and full contractor maintenance, which includes depot, field, and on-equipment activity. Four types of guarantees are also addressed in the table: reliability, maintainability, availability, and cost.

Table 5-1. WARRANTY-GUARANTEE APPLICATION CRITERIA

Criteria	Rationale	Warranty*						Guarantee**			
		Depot [illegible]		Depot and Field		Depot, Field, and On-Equipment		R	A	M	C
		Local	Remote	Local	Remote	Local	Remote				
Procurement Factors											
The procurement is to be on a fixed-price basis.	The provisions of ASPR provide that contractor warranty clauses are admissible under a cost-type contract, thus removing the inherent penalty for poor performance if the contract is not of a fixed-price form. Guarantee prices may be fixed price or could be negotiated in terms of target costs and sharing ratios.	1	1	1	1	1	1	1	1	1	1
Multi-year funding for warranty-guarantee (W-G) is available.	To realize the full potential of W-G, the W-G period must be long enough to provide the contractor strong incentive to achieve and maintain W-G objectives. Sufficient funds to cover such multi-year activity must be budgeted.	1	1	1	1	1	1	1	1	1	1
Warranty administration can be efficiently accomplished	The success of a W-G program requires that careful attention be given to the plan for W-G administration. The administration plan must include identification of material flow paths, cognizant agency responsibilities and procedures, and generation of requisite data to implement W-G terms and conditions. Since DCAS will ordinarily have heavy responsibilities for in-plant contractor performance, such involvement must be considered.	2	2	1	1	1	1	2	1	1	1
The procurement is competitive.	Competition among offerors will promote analysis of risk situations and development of realistic prices in response to the risk. Without competition, there may be a tendency to simply add a contingency cost to cover risk.	1	1	1	1	1	1	1	1	1	1
Potential contractors have proven capability, experience, and cooperative attitude in providing W-G commitments.	Experience and capability in maintaining similar equipment will provide contractors a basis for pricing warranty realistically and for successfully performing warranty tasks. Reluctance to accept a warranty provision may be due to lack of understanding of warranty terms and conditions.	2	2	2	2	2	2	2	2	2	2
An escalation clause is included in the contract that is applicable to W-G costs.	Unless such a clause is included, contractors may tend to "price in" an abnormally high price-risk factor to account for price-level uncertainties.	3	3	3	3	3	3	3	3	3	3
The equipment will be in production over a substantial portion of the W-G period.	Warranty repairs can be interleaved with production activity. ECPs can be introduced into the population more quickly. Consignment spares can be less expensive to develop if a production line is still active. In general, there is an improved opportunity for feedback of information into the population of units under W-G	3	3	3	3	3	3	2	2	2	2
Equipment Factors											
Equipment maturity is at an appropriate level.	W-G would not be appropriate for items which are (a) truly state-of-the-art or high-technology designs with little or no commercial or military usage. (b) very mature in design and offer little or no opportunity for growth once deployed. In the first case, the contractors may be subjected to extreme risks if required to bid W-G. In the second case standard production and operational tests may be sufficient to confirm that acceptable equipment is being produced. W-G candidates are intended for use or proven [illegible] which are entering production and which can benefit from feedback to the contractor of field results	1	1	1	1	1	1	1	1	1	1
[illegible] marked or labeled [illegible] existence of W-G coverage	An effective means of communicating the existence of W-G coverage is suitable marking of the item itself. Items that cannot be marked because of their physical size (too small) or the nature of their external surface (highly irregular) may not be good candidates for W-G.	1	1	2	2	N/A	N/A	3	3	3	3
[illegible] operation [illegible]	[illegible] is highly dependent upon the performance of other equipment, it may be difficult to determine which equipment is at fault during a system failure.	2	2	3	3	N/A	N/A	2	2	2	2
[illegible]	[illegible] failure from handling and [illegible] frequency of warranty [illegible] events in [illegible]	2	2	3	3	3	3	2	2	3	3

*Numbers represent [illegible] importance of the criterion for the type of warranty or guarantee: 1 = Major, 2 = Secondary, 3 = Minor. See accompanying [illegible]

**R = Reliability, A = Availability, M = Maintainability, C = Logistics Support Cost.

Table 5-1. (continued)											
Criteria	Rationale	Warranty*						Guarantee**			
		Depot Only		Depot and Field		Depot, Field, and On-Equipment		R	A	M	[illegible]
		Local	Remote	Local	Remote	Local	Remote				
Equipment Factors (continued)											
An ela[illegible]e-time [illegible]icator ([illegible]TI) [illegible] installed [illegible] the equipment.	[illegible]TI [illegible] accurate measurement of operating time [illegible] permitting more complete assess[illegible] [illegible] failure rates, and trends.	3	3	3	3	3	3	2	2	3	2
Unit has no failure mode that would lead to additional damage to itself or other units if not corrected.	Remote operation of equipment must not cause additional damage due to unattended operation.	N/A	2	N/A	2	N/A	2	N/A	N/A	N/A	N/A
Operational Factors											
Use environment is known or predictable.	In order for the contractor to effectively evaluate and price his [illegible] liability, information on the expected use environment, including operating rates, must be available to him. Such information is also required by the contracting agency to permit independent evaluation of price.	1	1	1	1	1	1	1	1	1	1
Equipment operating reliability and maintainability are predictable.	Estimating reliability is important for determining the expected number of failures, and estimating maintainability is important for determining expected repair costs. Too much uncertainty in such estimation may expose the contractor to undue risks. Designs containing a significant quantity of new part types for which there is no method of predicting reliability may not be good candidates for [illegible] coverage.	1	1	1	1	1	1	1	1	1	1
Equipment wartime or mission peacetime criticality is not of the highest level.	Any reduced self-sufficiency arising from warranty maintenance must be tolerable in a wartime situation or in highly critical peacetime missions. Even though the government has the authority to request expanded services, timely plans must be made for implementing wartime provisions and/or organic-maintenance takeover. It may be desirable to suspend guarantee requirements in wartime if data collection is affected.	1	1	2	2	3	3	3	3	3	3
Operational failure and usage information can be supplied to the contractor.	To determine conformance with [illegible] commitments, pertinent failure and usage information should be supplied to the contractor as expeditiously as possible.	2	2	3	2	N/A	N/A	1	1	1	1
Backup warranty repair facilities are available.	In order to minimize the disrupting effects of strikes or natural disasters, it is advantageous to have a contractor who can maintain a backup facility remotely located from the main facility.	3	3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Provision can be made for computing the equipment's MTBF.	Comparison of the observed with the guaranteed MTBF is the key element in determining compliance with [illegible].	N/A	N/A	N/A	N/A	N/A	N/A	1	1	N/A	1
Support Factors											
Control of unauthorized maintenance can be exercised.	Items whose construction precludes the installation of seals or other control mechanism at the authorized level of maintenance are considered to be poor candidates for [illegible] unless careful maintenance-to-[illegible] disciplines can be exercised.	1	1	2	2	N/A	3	1	1	1	1
Unit is field-testable.	Since compliance with most warranties will require the failed unit to be returned to the vendor, it is important that the unit be field-testable to determine if it is in a "go" "no-go" state. Lack of field testability can greatly increase cost of support because of the requirement for additional pipeline spares plus the added expense of tests for good items by the contractor. Guarantees must recognize field testability levels in establishing target parameter values and in accounting for "Retest OK" items.	1	1	N/A	N/A	N/A	N/A	2	2	2	2
								Guarantee must recognize testability levels when targets are being established.			
Number of site maintenance personnel tend to be independent of equipment performance.	If this is true, contractor may have little ability to influence true logistics costs. Emphasis must then be put on operational factors.	2	2	1	1	1	1	1	1	1	1
Rapid restoral time is required.	Explicit definitions of equipment up-time and downtime are required in this situation.	N/A	N/A	3	2	3	2	3	3	1	1
Proper operation may be remotely sensed.	Means are required to determine if remotely located items are failed [illegible] explicit definitions of equipment up-time and downtime are required in this situation.	N/A	N/A	N/A	3	N/A	3	3	1	1	3
[illegible]nomic [illegible]actors											
The [illegible] reliability, maintainability [illegible]	[illegible] MTBF [illegible]	[illegible]	[illegible]	[illegible]	1	1	1	1	1	[illegible]	[illegible]

In the body of the table, each application criterion has been assigned an "importance factor" that assesses the relative importance of each criterion to each warranty-guarantee plan. These factors are interpreted as follows:

1. Major - Failure to meet stated criterion could be grounds for rejecting this warranty-guarantee plan or, at the least, could require a reassessment of the goals or implementation methods for the warranty-guarantee.
2. Secondary - Failure to meet stated criterion would generally not be grounds for rejecting this warranty-guarantee plan. However, special attention must be given this point in developing a specific approach. Several secondary grades for a warranty-guarantee could be cause for rejecting the approach.
3. Minor - Failure to meet one or more of these criteria is generally not cause for rejecting this warranty-guarantee plan. However, special consideration should be given to these points in structuring the warranty-guarantee contract.

It should be noted that in several cases the numerical importance factor changes with different warranty levels, or becomes nonapplicable (N/A). For example, warranty administration becomes more critical as the warranty changes from depot only to depot and field, or to depot, field, and on-equipment. With the contractor having full responsibility in the last case, the Government must have the ability to assure contract compliance at all three levels, not only at the contractor's depot facility. Alternatively, under the depot-only warranty, it is relatively important that the Government be able to provide operational failure and usage information to the contractor. However, under the depot, field, and on-equipment warranty this factor is N/A since contractor representatives will be on site and will be responsible for their own failure and usage information.

5.2 DISCUSSION OF INDIVIDUAL CRITERIA

The following sections address the criteria areas that appear in Table 5-1.

5.2.1 Procurement Factors

The circumstances under which the warranty-guarantee equipment and the warranty-guarantee are procured will affect the applicability of various approaches. Although these criteria have almost equal impact across the warranty-guarantee alternatives, they can help to determine if the procurement circumstances are consistent with warranty-guarantee needs.

5.2.2 Equipment Factors

Equipment factors examine the basic design features of the equipment being procured. In many cases these factors are under the control of the development contractor and may differ among contractors.

5.2.3 Operational Factors

Operational factors are related to the anticipated operational use of the equipment being procured. Most of these factors are established by the Government, although some contractor influences also appear here -- for example, the ability to estimate operational R&M characteristics. While the Government may have historical data on similar classes of equipment or field performance for similar-technology devices, contractors may have a wide variety of experience or no experience in the type of equipment being procured.

5.2.4 Support Factors

Support factors examine aspects of equipment support that are not specifically performance-related.

5.2.5 Economic Factor

The economic factor is perhaps the most important in Table 5-1. Unless sufficient maintenance (or other) activity is anticipated, a warranty plan will become only a maintenance contract and guarantee compliance will be judged on the basis of highly variable quantitative estimates, which may be challenged by a contractor if he is subject to significant cost impacts. Chapter Six addresses the economic analysis of warranty-guarantee in detail.

CHAPTER SIX

ECONOMIC ANALYSIS

Previous chapters have reviewed a number of qualitative factors to be considered in deciding how or when to use a warranty or guarantee plan. This chapter describes methods for evaluating the economic implications of the use of one or more incentive plans.

6.1 PURPOSE AND BASIS FOR ECONOMIC ANALYSIS

Economic analysis is performed to determine the financial feasibility of a warranty program. The evaluation consists of determining the expected life-cycle cost for the warranty alternative versus the cost expected to be incurred if the system were supported under normal organic maintenance. To perform the economic comparison, a life-cycle-cost (LCC) model is used. Such a model has been developed as part of this effort and it has been formulated to represent the factors of concern related to the ground system environment. The analysis performed can more truly be represented as a comparative analysis since cost elements that are the same regardless of the approach -- e.g., installation cost, power, -- are not considered as part of the analysis.

The model for the warranty case computes the acquisition, spares, and preventive and corrective maintenance cost to be incurred by the Government, together with applicable AGE, training, and data costs. The warranty price can be inputted or can be estimated by the model. For normal organic support, the model computes the life-cycle cost, reflecting the designated maintenance concept. The model permits alternative concepts such as different maintenance concepts or warranty periods, to be rapidly evaluated. Table 6-1 summarizes the cost categories considered, together with their applicability to organic and warranty LCC analyses. Evaluation of warranty, including the case in which an MTBF guarantee provision is included in the warranty clause, is discussed in Sections 6.2 and 6.3. Special considerations regarding guarantee cost analysis are discussed in Section 6.4. These considerations include alternative methods for estimating guarantee costs which, coupled with use of the LCC model, provide a basis for economic analysis.

6.2 THE NEED FOR WARRANTY ECONOMIC ANALYSIS

Warranty Economic analysis may be performed at several points in the system life cycle. Table 6-2 summarizes the principal points of application. Subsequent paragraphs discuss the application in more detail.

Table 6-1. WARRANTY COST CATEGORIES		
Cost Category	Applicability*	
	Organic Maintenance	Warranty
Acquisition	X	X
Initial Spares	X	X
Replenishment Spares	X	X
Corrective Maintenance	X	X
Preventive Maintenance	X	X
AGE	X	L
AGE Support	X	L
Training	X	L
Data	X	L
Inventory Management	X	X
Warranty Price	-	X
Guarantee Value	-	X
Other	X	X

*Codes: X = Applicable, L = Limited, - = Not Applicable.

6.2.1 Validation/Full Scale Engineering Development

Although warranty is applied during the production phase, planning for its use must begin as early as the validation or full scale engineering development phases. At this point it is necessary to determine the basic economic feasibility of warranty or guarantee and to evaluate possible alternatives. Typically, during the early phases economic analysis can be made to determine the effect of various terms and conditions as they are being developed. If the terms and conditions are formulated at this stage, they can be included as part of the production RFP while there is still competition. In cases where competition ends at the validation phase, it may be necessary to use economic analysis to aid in making the final decision with respect to the use of the incentive concepts.

6.2.2 Production Source Selection

As noted, warranty applies to the production units; therefore, typically, the decision to obtain a warranty or guarantee must be made as part of the production source selection. The basic decision is concerned with determining if the warranty/guarantee cost being offered by the contractor is in

Table 6-2. WARRANTY ECONOMIC ANALYSIS	
Life-Cycle Phase	Purpose of Warranty Economic Analysis
Validation/Full Scale Engineering Development	• Determine economic feasibility of incentives • Evaluate various maintenance concepts and warranty plans • Evaluate alternate terms and conditions
Source Selection	• Evaluate economic advantage of incentive • Provide inputs to the decision for use of incentive • Provide inputs to source selection
Post-Production	• Evaluate warranty cost-effectiveness • Evaluate modifications to original warranty program • Acquire "lessons learned" for future programs

the best economic interest of the Government. This is determined by comparing the LCC with warranty against the LCC for total organic support. The cost of a guarantee has to be compared with the expected protection to the Government that such a cost represents.

The final decision to use a warranty requires consideration of many factors together with the economics. Unfortunately, there is no precise formula that can be used to aid the decision. If the general application criteria raise no obstacles and there is a clear cost advantage for warranty, a positive decision for warranty usually follows. Conversely, the failure to meet several of the general criteria, combined with a cost disadvantage for warranty, leads to a negative decision. There remain a number of cases that may fall in the middle ground, and these will require careful consideration. Here it is often necessary to examine the sensitivity of the final cost value as input parameters change and to consider the level of confidence with which the inputs can be accepted. The computer-based warranty model permits such analysis to be performed rapidly, aiding the decision process.

6.2.3 Post-Production Award

Economic analysis can be made following production award, to evaluate the actual warranty performance against the LCC projections. It may also be used to evaluate any possible changes in the warranty program. For example, additional uses of the equipment may be identified following award. Another military service may decide that the equipment being procured will

meet its requirements, or the equipment may be a likely candidate for Foreign Military Sales. An analysis may be conducted to determine the economic impact of revised production quantities, changes in installation schedules, or revised operational usage. Analysis and documentation following production award would also be valuable in providing "lessons-learned" for future programs.

6.3 DESCRIPTION OF WARRANTY LCC MODEL

The Warranty LCC model developed is a modification of the model previously developed for RADC under Contract F30602-74-C-0271. The earlier model, documented in RADC TR-76-32, *Guidelines for Application of Warranties to Air Force Electronic Systems,* was developed for avionics systems. Modifications were made to adapt the model to reflect the ground environment and to incorporate several improvements. Subsequent sections will address the scope of the model and the nature of any changes to model elements.

6.3.1 Model Cost Categories

As previously noted, the model computes applicable LCC elements for organic maintenance and for warranty with later transition to organic maintenance. The following sections describe each of these cost categories. Appendix A provides details concerning the method of evaluating each cost element.

6.3.1.1 Acquisition Cost

Acquisition costs include the cost of the equipment to be installed but not the cost of spares. The acquisition costs may be the same for both warranty and organic, but not necessarily. It is not unusual for a manufacturer to include such costs in a correction-of-deficiencies clause in the contract line item for hardware. If a particular program's cost is separately priced, it may still be appropriate to include it in the acquisition cost. An example is reliability program cost.

6.3.1.2 Initial Spares

The initial spares category includes the cost of recoverable spares required for support. In the basic sparing theorem employed, it is assumed that a Poisson process generates demand.

With respect to life-cycle cost, it is necessary to consider the spares cost associated with transition from warranty to organic maintenance. Generally, at the time of transition, there will be an excess of spare subassemblies. The approach taken was to assume that any excess spare subassemblies will be disassembled to be used for reparable-module sparing and that any remaining module deficiencies will require additional purchases. In addition, any complete excess subassemblies or any excess modules remaining after organic maintenance sparing requirements are satisfied may have value either for new-installation subassemblies or for parts requirements (modules).

6.3.1.3 Replenishment Spares

The replenishment spares category comprises the cost to the Government of purchasing expendable or throwaway modules to replace those which fail and are discarded. It does not include parts used by base or depot repair, which are included in labor rates; or condemned items not normally thrown away, which are included in corrective maintenance repair costs.

6.3.1.4 Corrective Maintenance

The corrective maintenance of equipment can be divided into on-equipment corrective maintenance and off-equipment corrective maintenance. It includes the cost (to the Government) of labor and material to perform corrective maintenance at the organizational level. Generally, such maintenance consists of a remove-and-replace action. However, certain types of equipment may require repair at this level.

Off-equipment maintenance consists of the intermediate and depot maintenance costs incurred by the Government, including labor, material, and transportation costs. Although the specific implementation varies for each concept, the cost elements incurred by the Government for this category will remain the same.

For organic maintenance, the cost elements are as follows:

- Labor and material for fault verification and module replacement
- Shipping and depot labor and material for units that are "NRTS'd*"
- Shipping and depot labor and material for reparable modules
- Replacement costs for condemned reparable modules

For warranty, the cost elements are as follows:

- Fault-verification base labor costs and incidental materials
- Cost of shipping units to and from the contractor if the Government pays for shipping

6.1.3.5 Preventive Maintenance

The preventive maintenance category includes the cost incurred by the Government for all preventive maintenance not performed by the contractor. This can include a resident staff performing periodic maintenance as well as a traveling staff that performs any special maintenance on a periodic (calendar or operating time) basis.

*NRTS = Not Repairable This Station.

6.3.1.6 AGE

The AGE category includes the cost of base and depot test equipment required to support the operating equipment. Generally, more complex test equipment will be required for organic maintenance than for warranty. However, at transition from warranty to organic repair, additional test equipment will be required, such as that needed at the depot level. Savings may be realized because the cost of additional test equipment is discounted.

6.3.1.7 AGE Support

Test equipment operation and maintenance cost is included in AGE support. It is calculated as a yearly percentage of the AGE acquisition cost. Different percentages may apply for the base and depot equipment.

6.3.1.8 Training

The training category includes the cost to the Government of training personnel to operate, support, and maintain the equipment. It includes both contractor-furnished and Government-sponsored training, as well as additional training that may be required at transition from warranty to organic maintenance.

6.3.1.9 Data

The data category includes the costs to purchase data associated with the equipment acquisition. Data for a warranty procurement are generally less extensive than for organic maintenance. Therefore, at transition, the costs to purchase any additional required data are included.

6.3.1.10 Inventory Management

Inventory management costs are the annual costs of managing items in the Air Force inventory. Only those items (parts, modules, units) which are unique to the equipment are included. For warranty, where maintenance is at the unit level, there will be many fewer unique items than for organic maintenance, where depot repair will require management down to the part or assembly level.

6.3.1.11 Warranty Price

The warranty price is the price paid to the contractor for supplying the warranty and associated data products.

6.3.1.12 Guarantee Value

For an MTBF guarantee the model computes the value accruing to the Government if the expected field MTBF of the equipment is below the guaranteed level. Such value is the discounted cost of the loaner spares consigned to the Government that will remain in the Government inventory after the warranty terminates.

Although the MTBF guarantee provision may involve several MTBF measurement periods and associated MTBF guarantee values, the model assumes a single measurement (based on the MTBF growth-data input values) to be compared with a single guarantee value. In addition to consignment spares, there are alternative forms of remedy if a guarantee is not met. These alternatives are discussed in Section 6.4.

6.3.1.13 Other Costs

Other costs include any LCC factors associated with a particular procurement that is not covered by the first 12 categories. Examples are costs to the Government of conducting an LCC verification test associated with organic maintenance, and costs to the contractor of transitioning to organic maintenance. For the warranty alternative, there are warranty administration costs. Government costs for procedures and staffing to administer the warranty are included in this element. Such factors as special data procedures, engineering personnel at the contractor's facility, and additional DCAS personnel might be included.

6.3.2 Model Factors

Formulation of the model required that a number of factors associated with the use of warranty for ground systems be considered. Major factors are reviewed here.

6.3.2.1 Maintenance Concept

The maintenance concept considers both corrective and preventive maintenance and sparing. Sparing levels and corrective maintenance costs have many different possibilities because of the different warranty levels possible (subassembly or module), the type of warranty (depot, depot and field support, and full contractor warranty), and the location of repair (on-equipment, intermediate, or depot). The model uses an integrated maintenance concept to incorporate the many possibilities. Essentially, the user of the model specifies a set of probabilities and pipeline times to describe the flow of subassemblies and modules from the organizational level through the depot level. Figure 6-1 illustrates the overall concept. A detailed explanation of Figure 6-1, together with an explanation of the associated probabilities, is provided in Appendix A.

In general terms, Figure 6-1 describes the flow of subassemblies and modules from their location on the equipment back to the depot. At node 1 (the equipment) a failure results in the removal of either a subassembly or module. (Alternatively, a fuse could be replaced, with no action required on either a subassembly or a module). The upper path in Figure 6-1 is the path that subassemblies take. Probabilities of different events occurring at each node are specified by the user. For example, at node 3 (intermediate-level maintenance) a subassembly could (1) retest "O.K." (2) be determined nonreparable and sent to the depot, or (3) be repaired by removing and replacing a module. The dashed line between nodes 3 and 6 indicates a reparable module being generated on the subassembly path and being sent to the module path at node 6. Once the various probabilities are estimated, the user has essentially determined the maintenance concept. Instructions for estimating the various probabilities are also included in the detailed explanation in Appendix A.

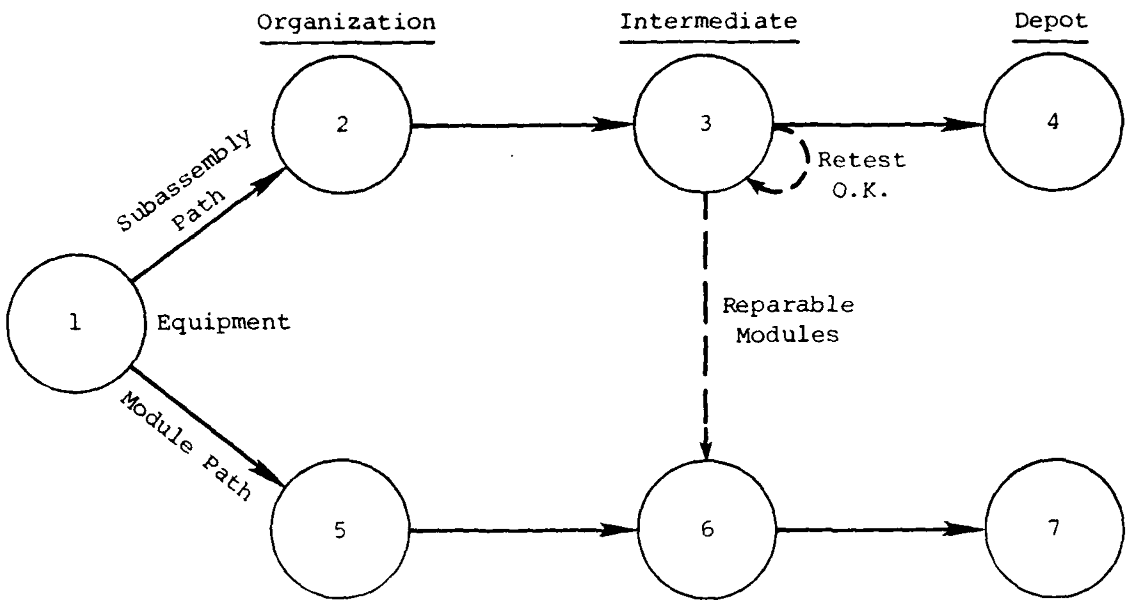


Figure 6-1. SUBASSEMBLY/MODULE MAINTENANCE FLOW

The model, as part of its internal processing, computes the number of spares required for subassemblies and modules at the base or intermediate level and at depot levels. The quantities are computed by using specific sufficiency criteria that consider both the probabilities of events occurring at the different maintenance levels and associated pipeline times. In addition, the model computes corrective maintenance requirements at each maintenance level for both subassemblies and modules. This computation is also determined in part by the probability that corrective maintenance action will be taken at a particular maintenance level.

Preventive maintenance is also considered at each maintenance level and must be specified in terms of man-hours per operate hour or man-hours per calendar period. Preventive maintenance cost may be applicable to both the warranty and organic maintenance cases and is controlled by inputs made by the analyst.

6.3.2.2 Maintenance Demands

Maintenance demands are generated by combining the number of failures and "false pulls". The model user inputs probabilities for "retest O.K." rates at the different maintenance levels for both subassemblies and modules.

6.3.2.3 Installs Schedule

The model permits the schedule of installs to be inputted individually, for each type of base. The schedule is inputted by year.

6.3.2.4 Peak-Spares Computation

The model will determine the year in which the peak number of spares is required for each support option in the period of interest. The model performs this task for each base type inputted and for the depot.

6.3.2.5 Reliability Measure

Mean time between failures (MTBF) is used as the measure of equipment reliability. The Duane growth model with a fixed upper limit is employed to reflect reliability growth. This permits different growth rates for full organic support, warranty support, and organic support following warranty.

6.3.2.6 Reliability Guarantee

The reliability guarantee is a guarantee that the system will attain a predetermined value of MTBF, which is usually specified at regular intervals through a guarantee period.

Although the MTBF guarantee provision may involve several MTBF measurement periods and associated MTBF guaranteed values, the model performs measurements only on the last period of interest. This procedure is invoked since only the last period determines the net effect of consignment spares.

Thus the model performs a single measurement (based on the MTBF-growth-data input values) to be compared with a single guarantee value at the time of interest.

6.3.2.7 Inflation

The model does not consider inflation, because the model outputs are intended for comparative analysis rather than for prediction or budgeting purposes. It is therefore important that all cost inputs be made in constant-year dollars to permit consistent analysis.

6.3.2.8 Discounting

The time value of money may be considered by using discounting. A discount rate of zero is equivalent to an undiscounted analysis.

6.3.2.9 Transition from Warranty to Organic Maintenance

The model assumes that the Government may defer buying support necessary for organic maintenance until transition to organic maintenance occurs. These delayed costs are included in the model, discounted as appropriate, when the warranty period is shorter than the equipment's useful life. AGE, training, and data purchased for the initial warranty are assumed to have full value for application to organic maintenance requirements at transition. Should this assumption not apply for a particular application, it can be corrected through an appropriate input in the "other" cost category.

6.3.3 Warranty Price

The analyst may input a warranty price, or the model will estimate a price. If the contractor bid values are available, they should of course be used. The model develops the required estimate for early feasibility studies or an independent cost assessment.

The following major cost elements are applicable to the contractor's pricing of a warranty:

- Fixed costs -- facilities and equipment
- Warranty repair costs
- Warranty administration and data costs
- Risk
- Profit

The generic warranty price estimation equation is as follows:

$$\text{Warranty Price} = \begin{pmatrix}\text{Risk}\\\text{Factor}\end{pmatrix} \times \begin{pmatrix}\text{Profit}\\\text{Factor}\end{pmatrix} \times \left\{ \begin{pmatrix}\text{Fixed}\\\text{Direct}\\\text{Cost}\end{pmatrix} + \begin{pmatrix}\text{Other}\\\text{Yearly}\\\text{Cost}\end{pmatrix} \right.$$

$$\times \begin{pmatrix}\text{Number}\\\text{of}\\\text{Warranty}\\\text{Years}\end{pmatrix} \times \begin{pmatrix}\text{Discount}\\\text{Factor}\end{pmatrix} + \left[\begin{pmatrix}\text{Corrective}\\\text{Maintenance}\\\text{Cost}\end{pmatrix} \right.$$

$$\left. \left. + \begin{pmatrix}\text{Preventive}\\\text{Maintenance}\\\text{Cost}\end{pmatrix} \right] \times \begin{pmatrix}\text{Discount}\\\text{Factor}\end{pmatrix} \times \begin{pmatrix}\text{Percentage}\\\text{for Data and}\\\text{Administra-}\\\text{tion Costs}\end{pmatrix} \right\}$$

6.3.3.1 Risk Factor

The risk factor is a single parameter incorporating the risk costs associated with the warranty. Rather than consider risk values for each of the cost elements, the contractor may price the warranty by using best estimates and then adjusting total warranty by a risk factor or, equivalently, using a higher profit factor. This simpler approach is used in the model. The risk factor has the following form if the warranty period is T_W years:

$$RSF = (1 + RSK)^{T_W}$$

where RSK is the risk factor for a one-year period expressed as a decimal.

It is noted that as the warranty period increases, so does the risk factor. The risk factor has a compound-interest form, so that the risk per year of warranty increases as the warranty period increases, which is probably more realistic than a simple-interest form.

6.3.3.2 Profit Factor

The profit factor represents the usual percentage of profit normally applied to Government contracts. In actual practice the contractor may combine the profit and risk factors. However, in the generic equation shown above they are separated to show the two separate factors that affect price; their separation also simplifies sensitivity analysis.

6.3.3.3 Fixed Direct Costs

Fixed direct costs represent special facilities and equipment that will be required to implement the warranty and that will not be included as part of overhead in the labor-rate data input. This cost element will be zero in many cases if all such fixed costs are included in the overhead factor for labor rate.

6.3.3.4 Other Yearly Costs

Included in other direct yearly costs are those costs, not included in other categories, which are dependent on the number of years of warranty. Examples are warranty data reports, test equipment support, technician training, bonded storeroom, and module sparing. If ODYC represents the sum of these other direct costs per year of warranty, the total other direct costs is given by the equation

$$TODC = ODYC \times T_W$$

where T_W is the warranty period in years.

6.3.3.5 Discount Factor

A significant portion of the contractor's expenditure for warranty takes place in the future. Therefore, discounting is necessary for analyses performed on a present-value basis. It is assumed that all but fixed direct costs will be discounted.

6.3.3.6 Corrective and Preventive Maintenance Costs

The contractor, depending on the particular warranty concept chosen, could be responsible for corrective maintenance of subassemblies and modules at all three maintenance stations (Organizational, Intermediate, and Depot). This cost is calculated by two means. A fixed number of man-hours per month can be established for corrective maintenance purposes. This ignores the actual system demand. A second means is to calculate the required repair hours by the number of system demands. Both means are employed in the computer model. The model chooses the larger value, which it then multiplies by the labor rates to find the cost. This cost is computed on a yearly basis in the computer model.

The contractor, depending on the particular warranty concept selected, could be responsible for preventive maintenance at all three maintenance stations. Like corrective maintenance, the preventive maintenance is calculated from a fixed manpower loading and frequency of service. The larger cost is chosen by the model. This cost is computed on a yearly basis in the computer model.

6.3.3.7 Data and Administrative Costs

Warranty data and administration costs include the variable contractor costs associated with administering the warranty and the costs of activities associated with data collection analysis. A simple expedient is used for this cost factor: the total warranty repair costs are multiplied by a constant factor to yield the warranty data and administration costs.

6.3.4 Life-Cycle-Cost Computation Alternatives

The model permits life-cycle costs to be calculated over the prescribed life cycle for four cases: (1) total organic maintenance over the life cycle; (2) a warranty for T_W years, followed by organic maintenance for the remaining years; (3) warranty over the complete life cycle, with no costs for transition to organic maintenance, and (4) warranty over the life cycle considered, plus costs to acquire complete organic maintenance capability. The difference between cases (3) and (4) is that for the former it is essentially assumed that the equipment will be phased out after the prescribed life cycle, while for the latter the equipment will still be used and transition expenditures will have to be made, such as for AGE, training, and data. Appendix A provides detailed instructions for use of the model. Chapter Nine contains an illustrative example of its use.

6.4 GUARANTEE COST ANALYSIS

In the Chapter Five discussions of guarantees, three forms of remedy were identified as compensation from a contractor in the event that specified guaranteed values were not met: cash, material (perhaps in the form of consignment spares), and services. The choice of a remedy will affect both the contractor's cost to provide a guarantee and the value that will accrue to the Government from the guarantee. The former (contractor's cost) is primarily applicable to pre-bid analysis and is examined in Sections 6.4.1 through 6.4.3. The latter (value to the Government) is primarily applicable after bids are received; this aspect is discussed in Section 6.4.4.

6.4.1 Cash Remedies

When a guarantee incorporates a payment schedule or payment adjustment schedule as a remedy, the analysis of a contractor's potential obligation is quite direct. In this case one can construct a schedule that relates

the contractor's financial obligation for each achieved value of the guaranteed parameter. Figure 6-2 is an example of such a schedule for the following situation:

- *The guaranteed MTBF is 500 hours (in accordance with contractually specified measurement methods).*
- If the achieved MTBF is between 400 and 500 hours, the contractor returns to the Government \$10 per system for each of the hours short of the 500-hour goal.
- If the achieved MTBF is less than 400 hours, the contractor will return to the Government \$1,000 per system, plus \$20 per system for each of the hours short of 400.

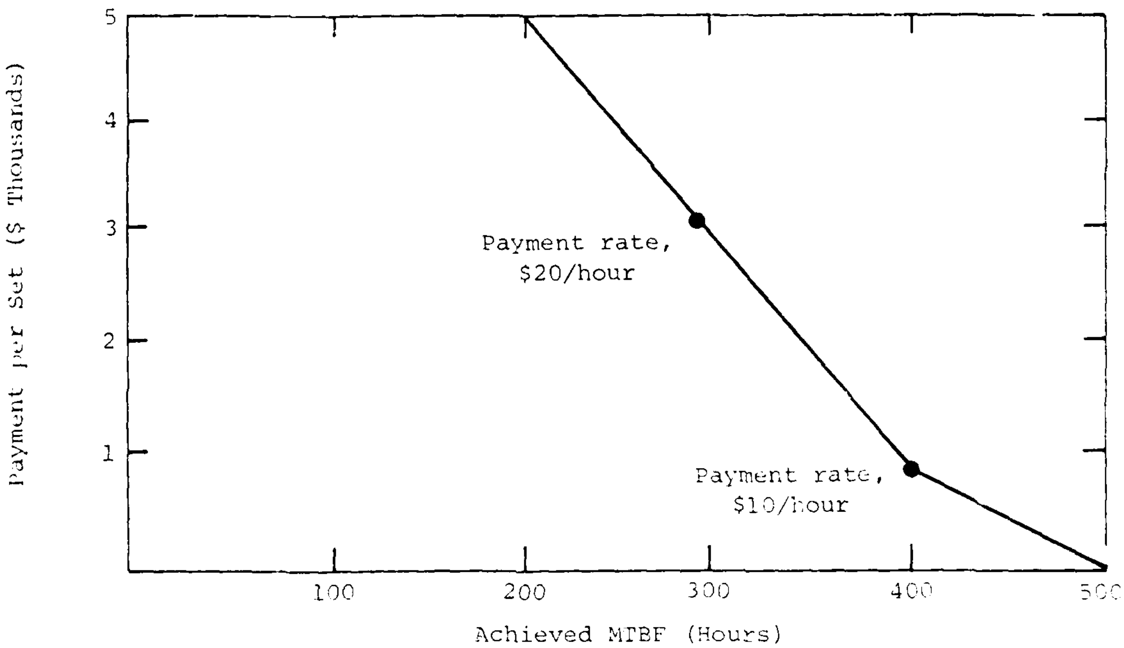


Figure 6-2. MTBF GUARANTEE SCHEDULE OF PAYMENTS

The contractor's direct cost is shown on the payment schedule. His actual costs must also cover those efforts needed to implement and administer the guarantee provisions of his contract. These efforts could include data collection and analysis, report preparation, failure analysis, and possibly field visits to establish failure circumstances. Many of these activities could be accomplished at a fixed level of effort regardless of achieved MTBF. However, failure analysis and field trip activities might be expected to increase for lower values of achieved MTBF.

Although Figure 6-2 describes a payment schedule related to an MTBF guarantee, similar schedules can be developed for the maintainability, availability, and cost guarantees discussed in Chapter Five.

6.4.2 Material Remedies

Under many existing MTBF guarantees, the contractor is obligated to supply consignment spares to the Government at no cost if guaranteed values are not met. With either a reliability or maintainability guarantee, it is possible to require a contractor to supply additional intermediate or depot test equipment if guaranteed values are not met. Some combination of these requirements can be made part of an availability guarantee.

The warranty-organic LCC model described in this chapter estimates the costs of consignment spares under the following assumptions:

- The service will support the equipment with a fixed number of spares (N) that is related to demand rates and a specified probability of sufficiency.
- The contractor can be required to supply up to N consignment spares where the actual number is given by

$$N(\text{consignment}) = N \times \min\left[\frac{G}{M} - 1,\ 1\right]$$

where G = guaranteed MTBF and M = achieved MTBF.

With these assumptions, Figure 6-3 shows the schedule of required spares as a function of achieved MTBF.

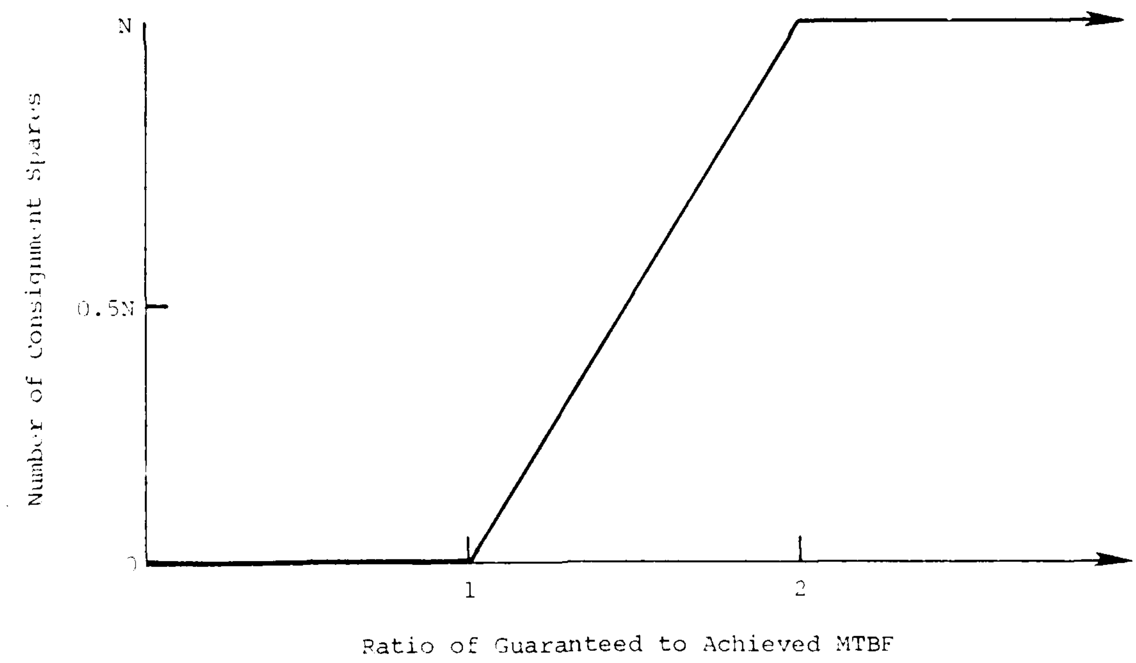


Figure 6-3. SCHEDULE OF CONSIGNMENT SPARES FOR TYPICAL MTBF GUARANTEE

In the LCC model, the MTBF guarantee is applied to and enforced at the subsystem level, and the cost of a consignment spare is set equal to that of a production item. The contractor's actual cost to build a consignment spare can vary significantly depending on the business strategy he adapts toward the guarantee. For example, he can choose to build potential consignment spares in parallel with production line efforts. The cost of these units will then be (approximately) the incremental unit cost for the last production unit. On the other hand, the contractor can choose to use guarantee money to intensify failure analysis efforts or field reviews to identify failure patterns. Or, on the basis of early field experience or other information, a contractor might decide to "wait and see." Then, if consignment spares are required, he risks having to pay premium prices for parts, long-lead items, and perhaps even labor required to deliver under the guarantee.

As in the case of the cash remedy, the contractor's price for a material remedy can include more than the spares indicated in Figure 6-3. Costs for data collection and analysis, report preparation, failure analysis, and field visits can also apply to the material remedy.

6.4.3 Services Remedies

Under the services remedy, the contractor can be required to provide engineering services to investigate the reasons for failure to meet the guaranteed value and then develop ECPs and modification kits (or changes to manuals, test equipment, etc.) to remedy the situation.

This is the most difficult alternative to analyze. The problem becomes apparent when one begins to develop a schedule of contractor cost versus an achieved parameter.

To illustrate this point, assume that the intermediate repair level MTTR is guaranteed to be 2 hours and that, under appropriate conditions, a 3-hour MTTR is achieved. The deficiency could be due to one or a combination of the following reasons:

- Inadequate built-in test
- Ambiguous resolution of faults
- Ambiguous or incomplete manuals
- Poor accessibility for fault isolation
- Excessive set-up times
- Intricate disassembly procedures to reach and replace failed items

Each of these, or other factors that contributes to the 3-hour MTTR could require a different cost to remedy.

A method of estimating the cost of a services remedy is presented in the following subsections. However, as the discussion in this paragraph indicates, an analyst must exercise caution in developing and using these estimates because of the nature of the phenomenon being estimated.

The guarantee cost estimate for this remedy has the form

Guarantee Cost = Cost (Engineering) + Cost (Implementation)

We assume that an engineering effort is required to identify the source of the problem and to develop changes or modifications, as required, to correct the problem. The implementation effort includes those costs necessary to produce modification kits, hardware changes, manuals, or test equipment changes.

6.4.3.1 Engineering Effort

Figure 6-4 illustrates the construction of a contractor cost schedule for the engineering effort associated with a services guarantee. Although we will assume a reliability guarantee, the analysis is essentially unchanged if other parameters are used.

In Figure 6-4(a), the abscissa identifies the guarantee parameter in terms of the applicable units (for a reliability guarantee, this could be MTBF), and the guaranteed value V_g is shown. The ordinate represents contractor cost, and in Figure 6-4(a) we assume that the contractor will incur a minimum cost (C_{min}) whenever the measured value falls below V_g.

In Figure 6-4(b) we have identified a second point on the cost schedule. Let V_{min} be the minimum value of the guaranteed parameter that could reasonably be expected in field operation. Let ΔC be the cost of a reliability engineering and analysis program (independent of the fixed cost C_{min}) that would improve the design from V_{min} to V_g. Two ways to estimate V_{min} and ΔC are:

- If the production effort is preceded by a development contract, V_{min} would be an estimate of MTBF (derated for field use) prior to development and ΔC would be the development and reliability costs related to the affected system or subsystem. In this case ΔC would be some fraction of the development program's cost.
- When the production effort is not preceded by a development contract, it might be possible to review other development programs of similar technology and complexity that have development eff[illegible]. Then V_{min} and ΔC could be estimated by using these data.

In each of these cases ΔC represents an *a priori* estimate of the design effort required to move an equipment's performance from V_{min} to V_g. It could be argued that if a design fails to meet a guarantee clause, then the development cost estimates must have been invalid. While there is some merit to the argument, it is also true that a large quantity of field data will be available when guarantee compliance is measured. Hence the ΔC costs can be f[illegible] on the problem areas and not distributed over the entire equipment. The resolution of this paradox lies in the fact that a range of [illegible] appear in a Figure 6-4 schedule for any given achieved value of the MTBF parameter. Thus estimates derived from any specific curve must be subjected to a sensitivity analysis to accommodate this variability.

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WARRANTY-GUARANTEE APPLICATION GUIDELINES FOR AIR FORCE GROUND --ETC(U)
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UNCLASSIFIED 1710-01-1-1996 RADC -TR-79-287 NL

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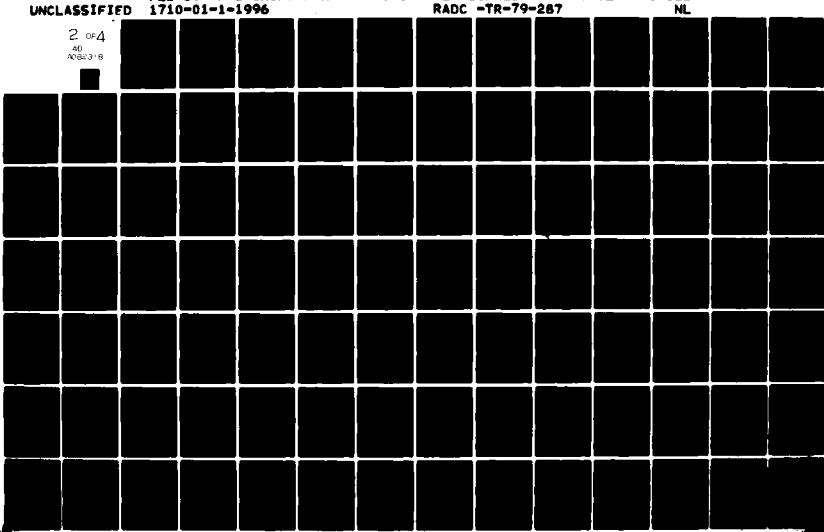


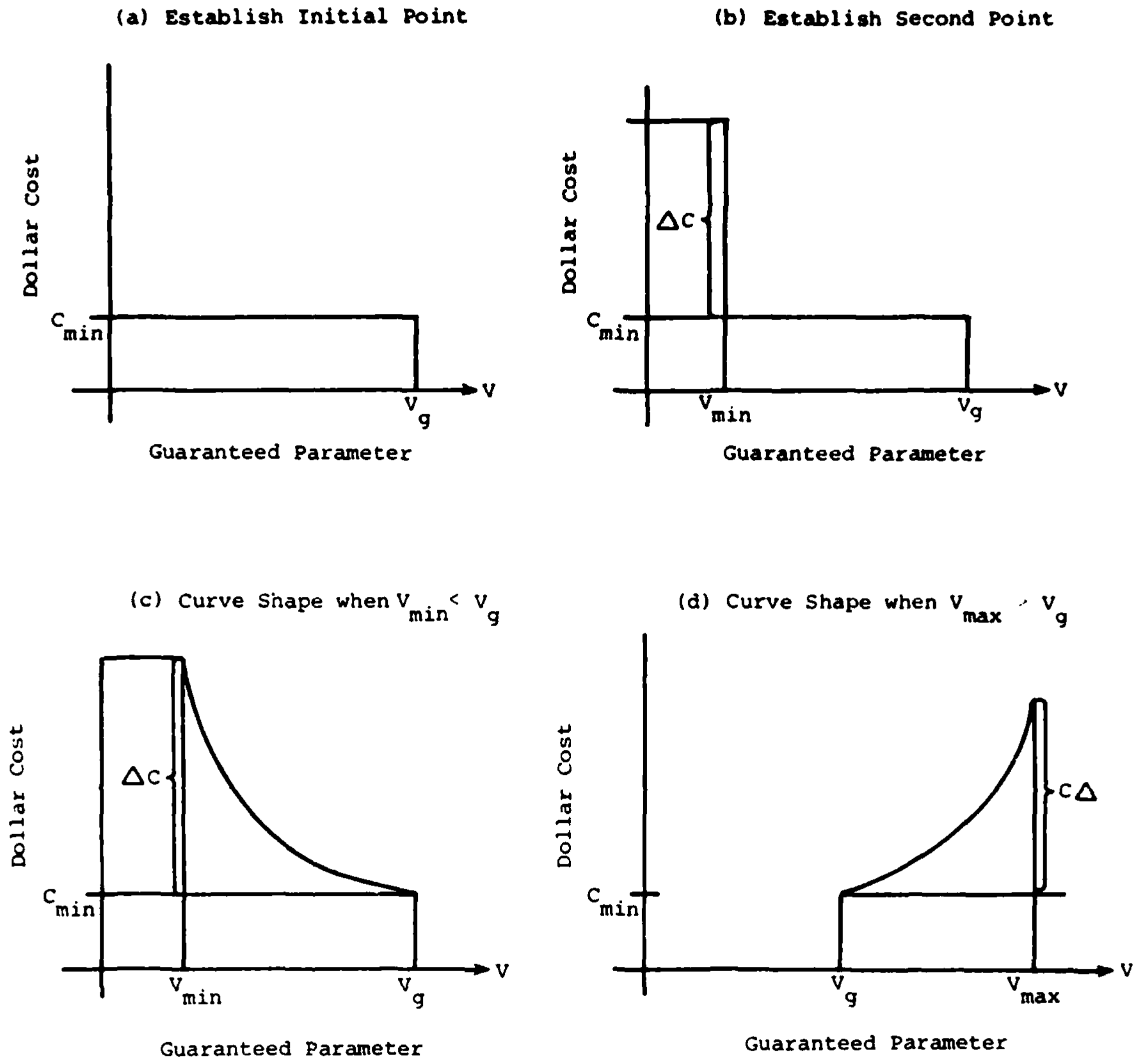


Figure 6-4. DEVELOPMENT OF ENGINEERING COST SCHEDULE FOR SERVICES GUARANTEE

Finally, we can generate a curve connecting the two previously established points if we make some assumption about its shape. In Figure 6-4(c) we have assumed that the cost (above the C_{min} value) grows as the square of $V - V_g$. While various exponents could be used, this "square of the error" approach is mathematically simple and reflects the fact that, whatever corrective action is available for small differences, successive increments of improvement become increasingly expensive as achieved performance moves farther away from the guaranteed value. For example, if an equipment fails to meet an MTBF guarantee, then a higher-quality mix of parts and increased equipment burn-in requirements can produce certain improvements. However, a point is soon reached where thermal redesign, circuit redesign, or custom-produced parts may be required at substantially higher cost per unit increase in MTBF.

The equation for the engineering-cost curve shown in Figure 6-4(c) is

$$\text{Cost(Eng)} = \frac{\Delta C}{(V_g - V_{min})^2} (V_g - V)^2 + C_{min}, \quad V_{min} \leq V \leq V_g \tag{6-1}$$

If we set $p = \frac{V}{V_g}$ (the ratio of achieved to guaranteed parameter values)

$$\text{Cost(Eng)} = \Delta C \left[\frac{V_g}{V_g - V_{min}} \right]^2 (1 - p)^2 + C_{min}, \quad \frac{V_{min}}{V_g} \leq p \leq 1 \tag{6-2}$$

This is a convenient form for analysis since the dimensionless variable p appears in a single factor that is separated from the other parameters related to the problem.

Equation 6-2 was derived on the assumption that V_{min} is less than V_g (as would be the case for an MTBF guarantee). Only minor changes are required to analyze the situation in which equipment is deficient when the achieved value is greater than a guaranteed value (i.e., MTTR or failure rate guarantees). This case is shown in Figure 6-4(d). Here V_{min} is replaced with a value $V_{max} > V_g$, and the equation for the curve is

$$\text{Cost(Eng)} = \Delta C \left[\frac{V_g}{V_{max} - V_g} \right]^2 (p - 1)^2 + C_{min}, \quad 1 \leq p \leq \frac{V_{max}}{V_g} \tag{6-3}$$

where, as before, $p = \frac{V}{V_g}$ is the ratio of the achieved to the guaranteed values for the equipment.

Finally, in using Equation 6-2 or 6-3, the analyst may need only to apply them to a portion of a system. For example, assume that the system has three subsystems and that the contractor, the Government, or both, already have extensive field experience with one subsystem. If it is believed that this subsystem is unlikely to contribute to failure to meet

a guarantee, the analysis should be based on the two subsystems that are potential problem areas.

6.4.3.2 Implementation Effort

For a services guarantee, the cost of implementation includes the costs necessary to produce modification kits, manuals, or test equipment modifications or hardware changes that are identified and developed during the engineering effort. Installation costs for these changes or the costs of physically modifying equipment or supporting items are not included in these costs, because many contracts require only that a contractor deliver appropriate modification kits or equivalent items. If a specific contract has other requirements, the cost of meeting them must be calculated separately.

Let A represent the part of the equipment that is expected to be affected by the modification effort. Let CA be the average production cost of A. Then, at the time a modification occurs, the replacement cost of A can be represented by k(CA) where k is a scaling factor that relates the replacement cost to the average production cost. The factor k could be greater or less than 1 depending on the size of the production run, the time at which the modification is required, and the nature of the changes that are expected to implement the modification (e.g., simply a change to higher-quality parts or a thermal redesign of a printed circuit card).

Finally, let pA represent the fraction of A that is affected by the modification ($0 \leq pA \leq 1$). Then the recurring cost of the modification is given by

$$C_r = (pA)k(CA),$$

and the the implementation cost over a population of N items is

$$\text{Cost(implement)} = N(pA)k(CA) + C_{nr} \qquad (6\text{-}4)$$

where C_{nr} represents the *nonrecurring* production costs for the modification. Equation 6-4 can be transformed into more basic parameters. Assume that CA is X percent of the average system cost (CS). Then

$$CA = \frac{X(CS)}{100}$$

$$N(CA) = \frac{NX(CS)}{100}$$

But N(CS) is the production cost estimate for N systems. If we represent this cost by CP, then Equation 6-4 becomes

$$\text{Cost(implement)} = \frac{(pA)kX(CP)}{100} + C_{nr} \qquad (6\text{-}5)$$

where

CP = original production cost estimate for N systems

X = percent of system cost represented by subsystem to be modified

k = scaling factor that reflects ratio of replacement cost to original cost for modified subsystems

pA = portion of subsystem affected by modification

C_{nr} = nonrecurring cost to produce modifications

6.4.3.3 Example

This subsection examines how these cost equations might be applied to a hypothetical procurement in which the MTBF guarantee requires development of modification kits if achieved MTBF falls below a guaranteed value.

System S consists of three subsystems: A, B, and C. Costs of a $5 million development program can be allocated as follows:

Item	Cost ($ Millions)
Subsystem A development	0.9
Subsystem B development	0.9
Subsystem C development	1.3
R&M program	0.5
Prototype development and other costs	1.4

Subsystems A and B are believed to be low-risk items under an MTBF guarantee on the basis of previous experience with similar designs. Subsystem C is to be guaranteed at 5,000 hours, and it is unlikely that it will exhibit less than 2,000 hours in the field. If the fixed costs for an engineering investigation of a deficient design are $0.05 million, what is the engineering cost estimated to be?

There is one item of information missing in this discussion: to what achieved MTBF level should the redesign effort respond? We will choose 4,000 hours as a baseline and 3,500 and 4,500 hours as checks on sensitivity of the resulting estimate. From the given information, Equation 6-2 is used to compute.

$$\text{Cost(Eng)} = \Delta C \left[\frac{V_g}{V_g - V_{min}}\right]^2 (1 - p)^2 + C_{min}$$

where

ΔC = \$1.5 million, which is the development cost of subsystem C plus 40 percent (an allocation) of the R&M programs attributed to the subsystem

V_g = 5,000 hours

V_{min} = 2,000 hours

$$p = 0.8 = \frac{4{,}000 \text{ hours achieved}}{5{,}000 \text{ hours guaranteed}}$$

C_{min} = \$0.05 million

$$\text{Then Cost(Eng)} = 1.5\left[\frac{5{,}000}{5{,}000 - 2{,}000}\right]^2 (1 - 0.8)^2 + 0.05$$

$$= 0.17 + 0.05$$

$$= \$0.22 \text{ million}$$

To test sensitivity:

3,500 hours achieved MTBF corresponds to $p = 0.7$ and Cost(Eng) = \$0.43 million.

4,500 hours achieved MTBF corresponds to $p = 0.9$ and Cost(Eng) = \$0.09 million.

To estimate implementation costs, assume that 100 systems are being purchased at \$250,000 each and that the average production cost of subsystem C is \$100,000. Further, by the time modification kits were developed, the replacement cost would be 20 percent higher because of inflation. Finally, if subsystem C is modular in design, assume that only 20 percent of it would be affected by the modification and that the nonrecurring production costs would be \$100,000. Equation 6-4 is used to compute

$$\text{Cost(Implement)} = N(pA)k(CA) + C_{nr}$$

where

N = 100

pA = 0.20

k = 1.2, ratio of replacement to production cost

CA = \$0.1 million

C_{nr} = \$0.1 million

Then

$$\text{Cost(Implement)} = 100(0.20)(1.2)(0.1) + 0.1$$

$$= \$2.5 \text{ million}$$

The total cost for the guarantee is

$$\begin{aligned}\text{Cost(Total)} &= \text{Cost(Eng)} + \text{Cost(Implement)}\\ &= 0.22 + 2.50\\ &= \$2.72 \text{ million}\end{aligned}$$

This represents less than 11 percent of the system price of $25 million.

The major subtotal in these implementation costs varies directly with either N, the quantity affected, or pA, the proportion of the system expected to be affected by the modification. If, for example, pA were estimated to be 0.10 or N were only 50, then

Cost(Implement) = $1.3 million

If the pA = 0.10 assumption is used, the total cost is reduced to $1.5 million, or 6 percent of the equipment acquisition price.

6.4.3.4 Summary of Services Guarantee Cost

The services guarantee cost is the most difficult to estimate of all those examined in this report. At the same time, any estimating procedure will provide a volatile estimate because of the nature of the assumptions that support the estimate.

6.4.4 The Value of a Guarantee

The preceding sections have addressed methods for estimating guarantee costs. However, once a bid is submitted as part of an offerer's cost proposal, the Government has the problem of determining whether on not accepting the bid is in its own best interest. The problem can generally be stated as follows (see Figure 6-5):

Let LCC ($X = X_0$) be the life-cycle cost of a system when the value of the guaranteed parameter X(such as MTBF) just equals the guaranteed value X_0. If the Government buys a guarantee for X at a price of $G(X_0)$, system life-cycle cost becomes

$$LCC\ (X = X_0) + G(X_0)$$

But this price is exactly the LCC for the system at a lower value of X, say

$$X_1 < X_0$$

Thus the decision to buy the guarantee can be restated as follows: "If you expect the system to perform at $X > X_1$, do not purchase the guarantee. If you expect the system to perform at $X < X_1$ and if the guarantee and other circumstances of procurement and deployment are such that X can be made greater than X_1, then purchase the guarantee." This condition reflects the breakeven point of a guarantee. Depending on the results to be expected without or with a guarantee, the price of a guarantee will be a better or worse "investment" in terms of return per dollar invested.

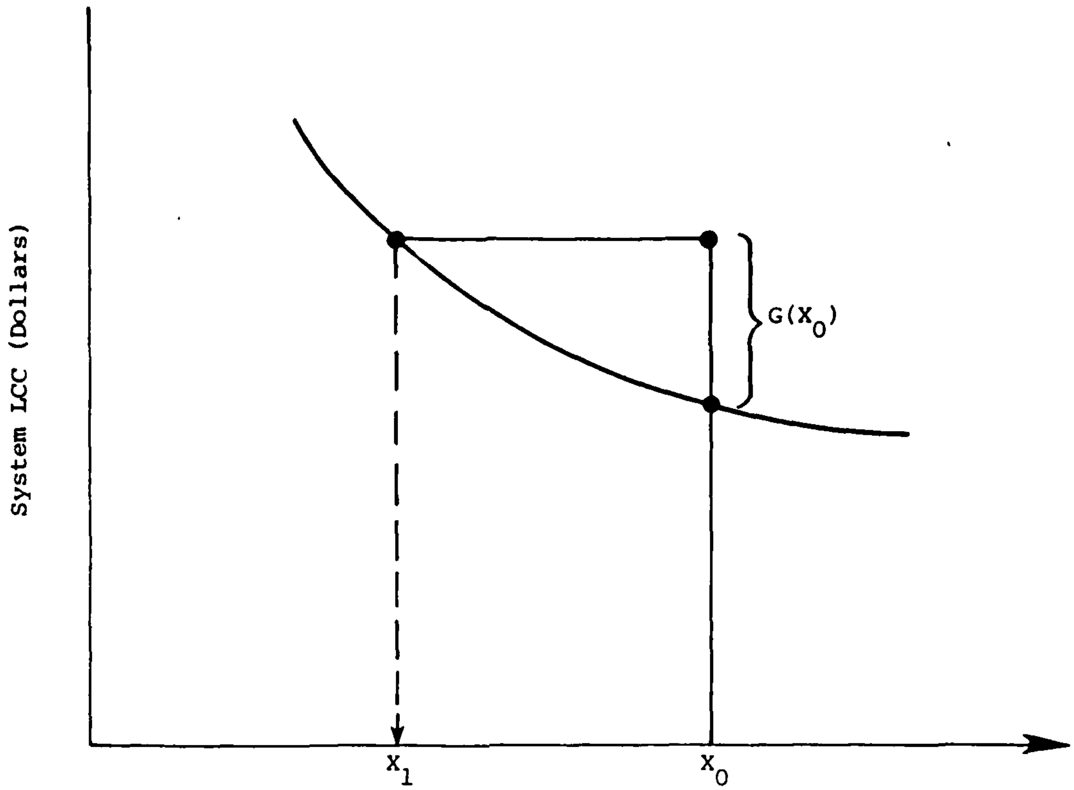


Figure 6-5. GUARANTEE COST ANALYSIS

In the following subsections, this analysis is applied, by example, to a hypothetical procurement.

6.4.4.1 <u>MTBF Guarantee Evaluation</u>

Once a bid is made on an MTBF guarantee, the decision whether or not to accept it depends on a number of assumptions that are made by the office that issued the solicitation. For example, assume the following:

1. If the measured MTBF exceeds that guaranteed, the contractor will take no action to improve MTBF.
2. If the measured MTBF is lower than that guaranteed, the contractor will take action to bring the MTBF up to the guaranteed value.
3. The MTBF guaranteed bid is X dollars.

Figure 6-6 is a hypothetical schedule of LCC versus MTBF. If an MTBF of MTBF(G) is met, the corresponding LCC will be LCC(G) (point G). If it is assumed that the contractor's bid to guarantee MTBF(G) is X dollars, the LCC is increased to LCC(G) + X, which is denoted by LCC(B). LCC(B) cor-

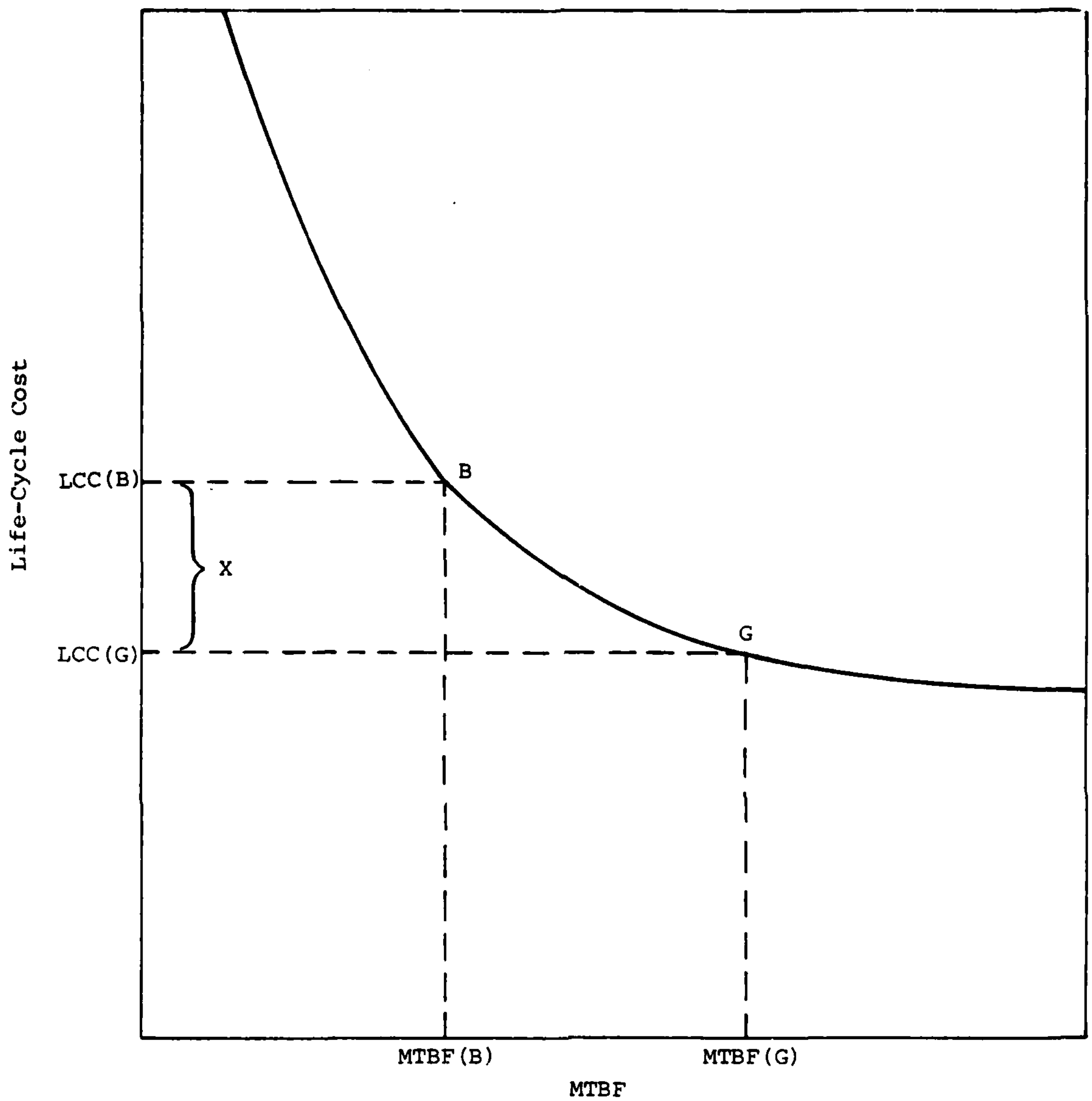


Figure 6-6. LCC VERSUS MTBF

responds to MTBF(B) (point B), which is less than MTBF(G). Then the following choices are available:

- If the achieved MTBF is expected to be less than MTBF(B) without the guarantee, then the guarantee bid should be accepted. Under assumption 2 above, the contractor will take action necessary to bring the MTBF up to at least MTBF(G).
- If the achieved MTBF is expected to be above MTBF(G), the guarantee bid should not be accepted. Under assumption 1 above, the contractor will take no action to improve the MTBF.

- If an achieved MTBF between MTBF(B) and MTBF(G) is expected, the bid should likewise not be accepted. If it is, the contractor is expected to improve the MTBF; but acceptance of the bid raises the LCC to a point above LCC(B), and all MTBFs above this point already have LCCs less than this.

Figure 6-7 shows the LCC versus average MTBF for a five-year warranty period. Data for the figure were obtained from model runs used for the sample application developed later in Chapter Nine. The LCC includes the price for a five-year warranty but does not include a price for an MTBF guarantee. As can be seen from the figure, if an average MTBF of 3,500 hours is obtained, the LCC is $18.04 million. If the contractor bids $200,000 to guarantee this value, the resulting LCC of $18.24 million equates to an average MTBF of 2,700 hours. Therefore, if an average MTBF below this number is expected, the bid should be accepted; otherwise, it should be rejected because the bid price increases the LCC to a higher value than that for 2,700 hours.

6.4.4.2 Availability Guarantee Evaluation

The evaluation of a bid on an availability guarantee is more complex since two independent variables, reliability and maintainability, are used in the calculation of availability. However, one approach is to begin with assumptions similar to those used in evaluating the MTBF guarantee. For example:

1. If measured availability exceeds specified, the contractor will take no action to improve availability.

2. If the measured availability is less than the specified, the contractor will take sufficient action to bring availability up to the specified value.

3. The specified availability is 0.90, and the expected MTTR and MTBF values are 10 and 100 hours, respectively.

Figure 6-8 shows hypothetical LCC estimates for five combinations of MTTR and MTBF centered on the nominal values of 10 hours and 100 hours, respectively. In Figure 6-9 iso-LCC curves have been drawn. These are approximations for the purposes of this example. The $9 million curve passes through (5, 100); the $10 million curve passes through (10, 100), the the nominal values; the $12 million curve passes through (15, 100).

The complexity of the evaluation problem becomes apparent in Figure 6-10 when iso-availability lines representing 0.85, 0.90, and 0.95 availability are added. The iso-cost and iso-availability lines are not parallel. In Figure 6-10 there are MTBF and MTTR combinations that meet the required availability at a higher or lower LCC than the specified point (e.g., points P and Q). On the other hand, there are points with the same LCC as point (10, 100) that do not meet the availability specification (e.g., point R).

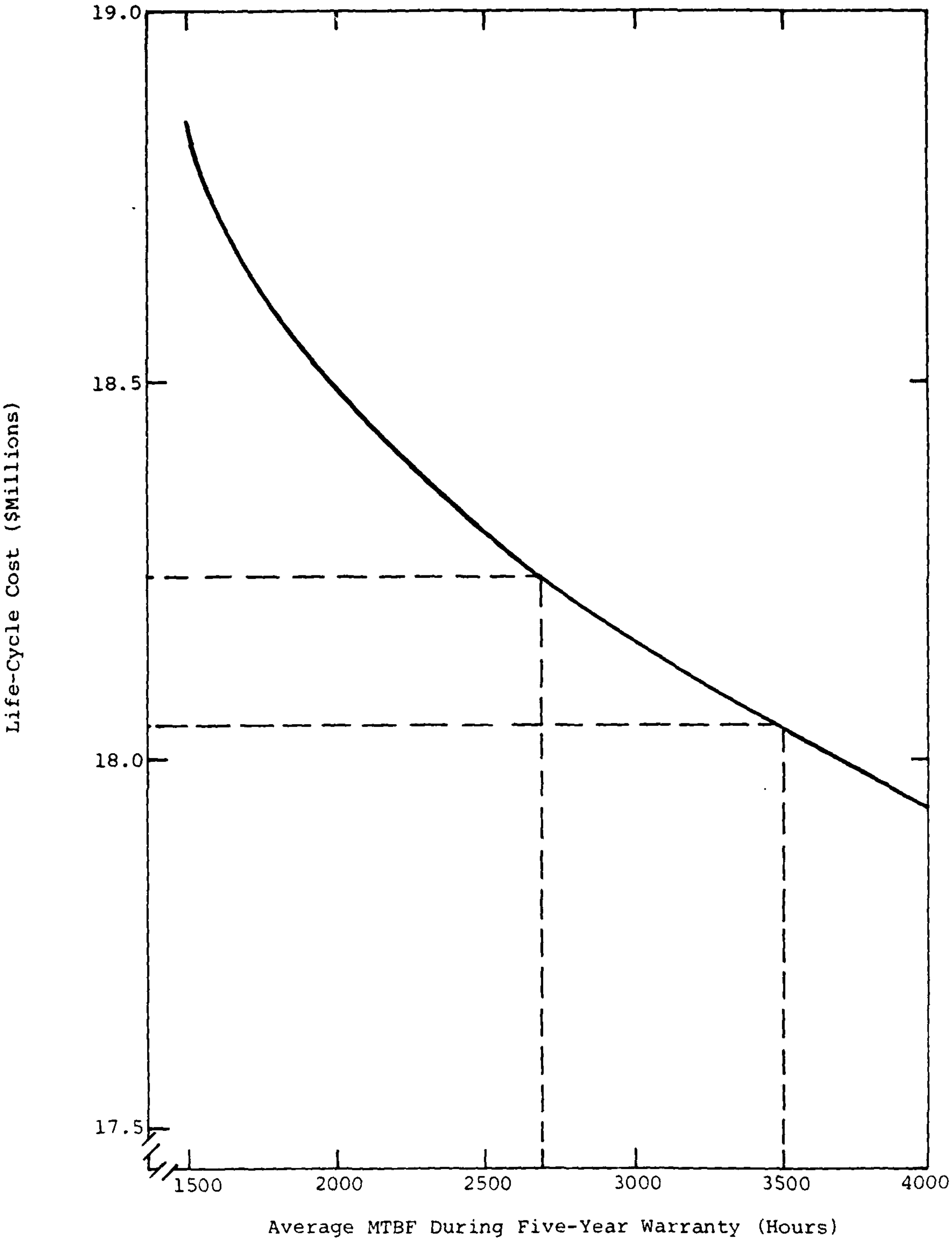


Figure 6-7. LCC VERSUS AVERAGE MTBF

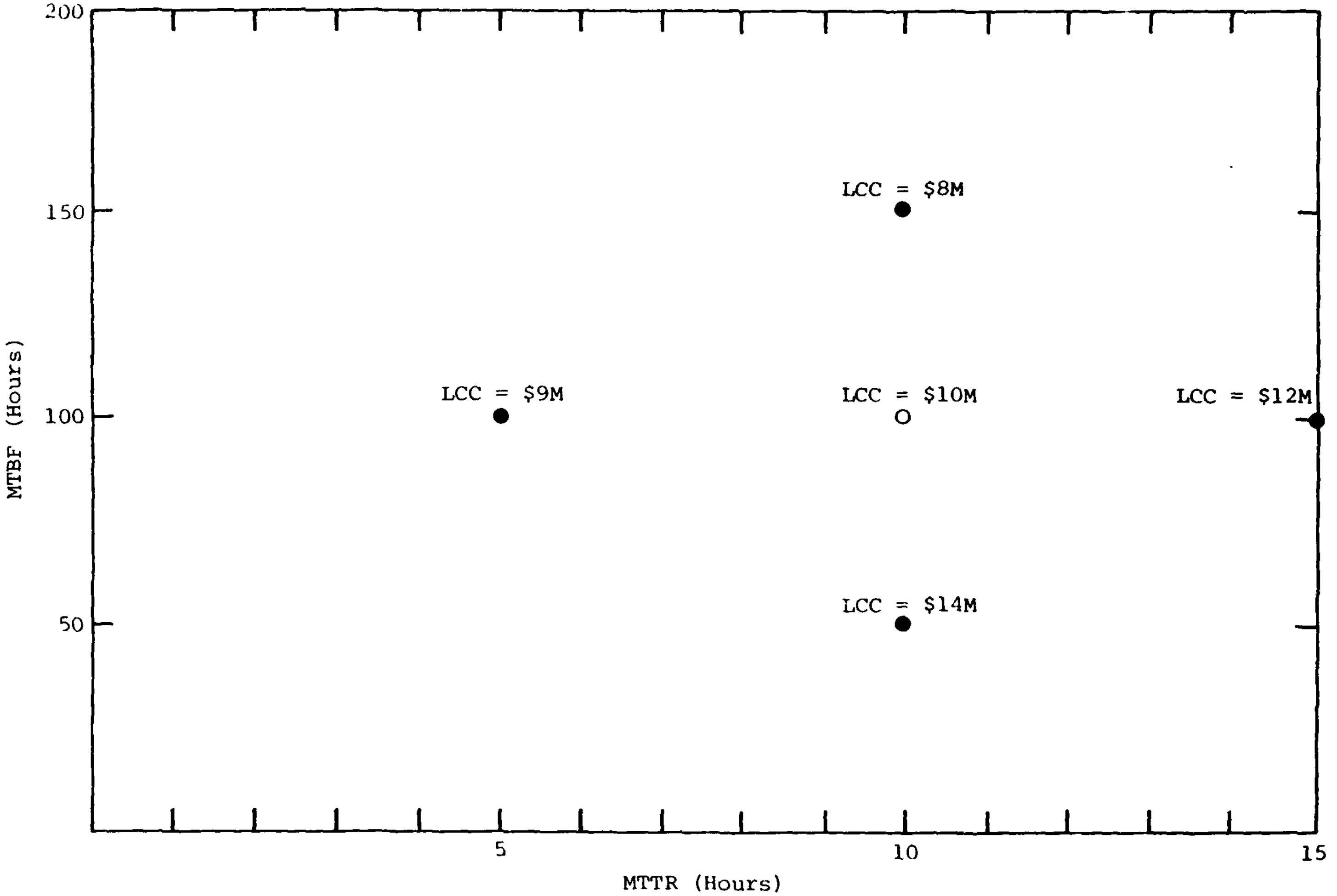


Figure 6-8. LCC FOR FIVE COMBINATIONS OF MTBF AND MTTR

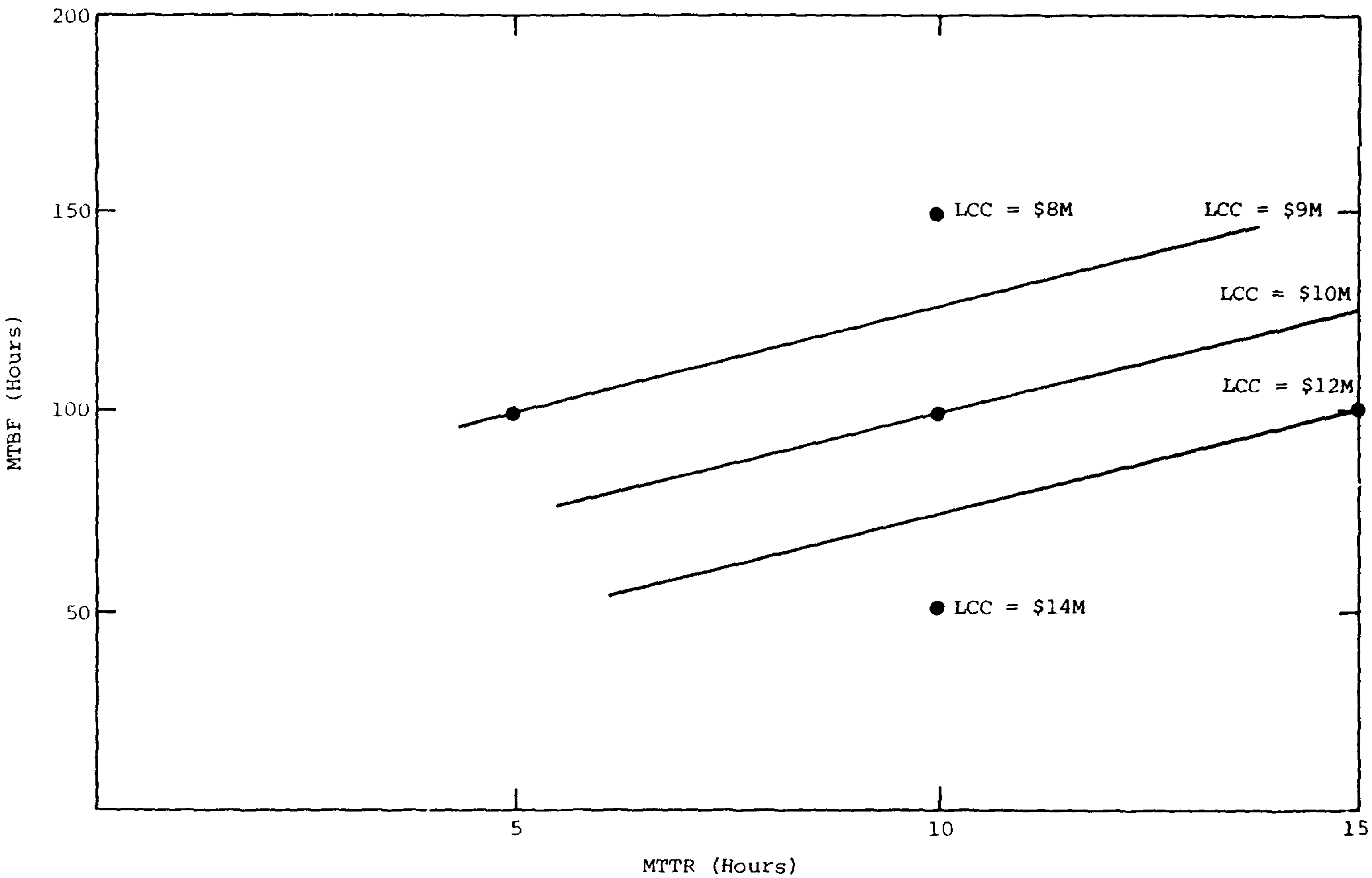


Figure 6-9. ISO-LCC CURVES ADDED TO FIGURE 6-8

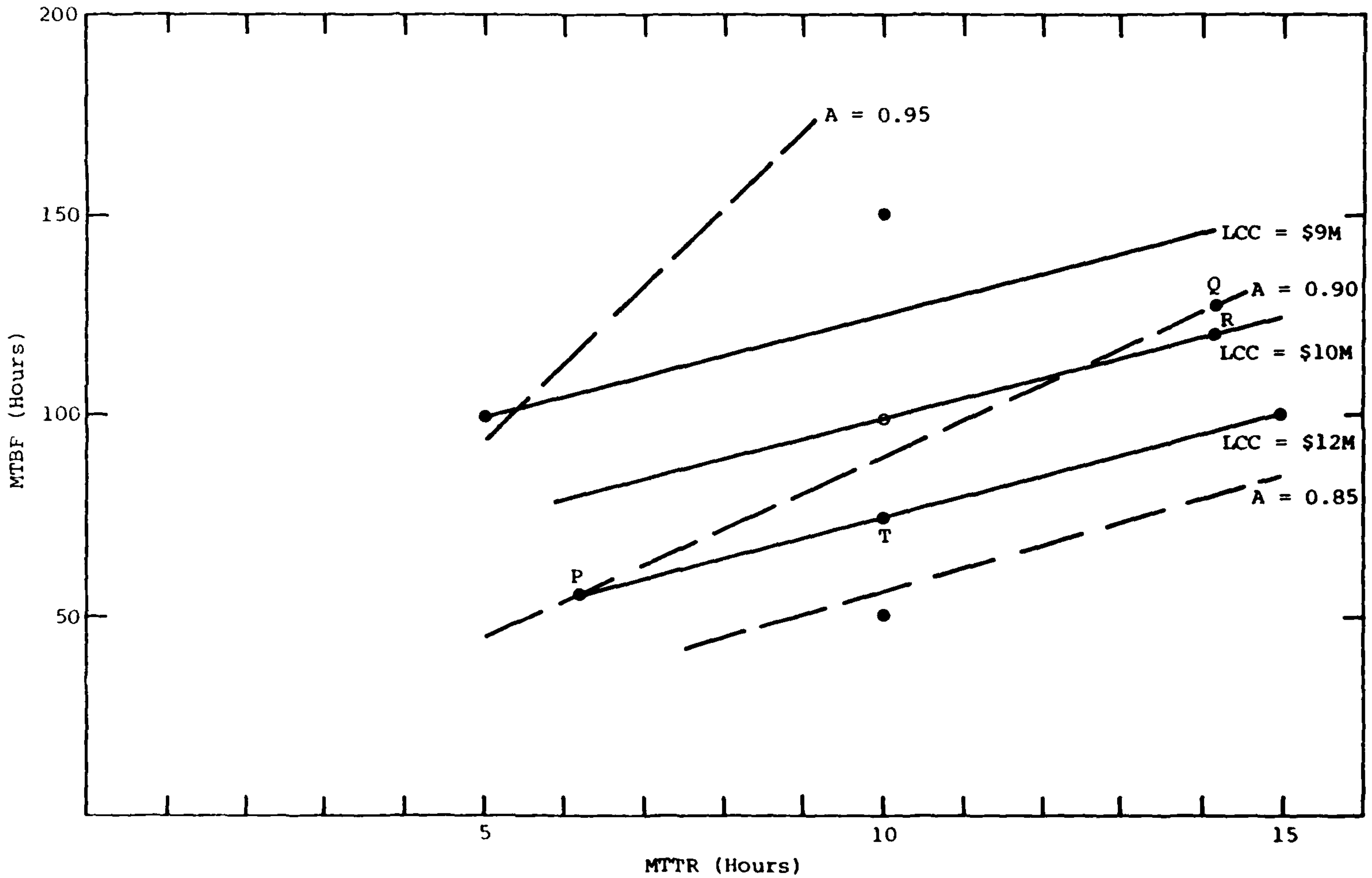


Figure 6-10. ISO-AVAILABILITY CURVES ADDED TO FIGURE 6-9

The value of the availability improvement expected under assumption 2 is difficult to evaluate. For example, point R, which does not meet the specified availability, has a lower LCC than point P, which does meet the goal.

Assume that initial availability measurements place the design at point T. If the contractor chooses only to improve reliability to meet the 0.90 requirement, this improvement would reduce LCC by $1 million to $2 million. If he chooses only to reduce MTTR, there is a different effect on LCC. To judge the potential worth of an availability bid, one must make additional assumptions on the improvement path the contractor will take (or the paths that might be available to him).

In this example it is assumed that the decision to accept or refuse an availability guarantee bid is strictly an economic one. For situations in which the availability need outweighs economic considerations (e.g., because of system criticality or other consequences of nonavailability), the foregoing analysis can only suggest the economic worth of the guarantee. If the bid price is above this amount, the excess represents the "premium" the Government must be willing to pay to achieve the specified availability.

6.5 SUMMARY

The economics of a contemplated warranty procurement is one of the most significant quantitative criteria for warranty evaluation. Use of the model for this evaluation requires several data inputs pertinent to the system, the Air Force, and the contractor. The economic analysis can compare life-cycle costs under a warranty with life-cycle costs where no warranty is employed. Such features as discounting, maintenance demands, warranty price, install schedule, cost of transition, and reliability measure are included and quantified.

The economic model is a trade-off between simplicity of usage and complexity of scope; it is valid for modeling the several aspects of a life-cycle-cost analysis. Several sensitivity analyses can be accomplished by employing a special data-change feature that allows the user to cycle through the program interactively without changing the initial input data files. Summary output data of pertinent aspects of LCC analysis are printed, and an option to print more detailed information is provided. The model also includes an MTBF guarantee that assigns a cost value to consignment spares and results in reduced life-cycle cost. Chapter Nine is a case study of a sample equipment that demonstrates the use of the model in performing an economic analysis.

CHAPTER SEVEN

WARRANTY-GUARANTEE PROVISIONS

This chapter is a discussion of provisions that are applicable to the warranty-guarantee concepts and plans introduced in Chapters Three and Four. The material is based primarily on three different sources: provisions previously developed in RADC TR 76-32, lessons learned from various applications of warranty, and the special circumstances encountered in the ground electronics area as discussed in Chapter Two.

Although there are advantages to making provisions consistent between two separate procurements (e.g., in warranty administration), the special circumstances of a given procurement will preclude a "cook book" approach in most cases. Therefore, this chapter addresses provisions in general terms. Special attention is given to cases in which a particular provision varies depending on the level of warranty or on the type of guarantee being applied. On the basis of information presented in this chapter, Appendix D provides specific language that may be used to construct a set of contractual warranty-guarantee provisions.

7.1 WARRANTY

Warranty provisions typically include three major parts:

- Part I - Statement of Contractor Warranty
- Part II - Contractor Obligations
- Part III - Government Obligations

Although the particular provisions required under each of these parts will depend on the specific application of interest, the following sections address key provisions that must be considered. In addition, they address situations in which a particular provision will vary depending on the level at which the warranty is applied.

7.1.1 Part I: Statement of Contractor Warranty

7.1.1.1 Warranty Statement

The warranty statement is the basic provision indicating that the contractor warrants that equipment furnished under the contract shall be

free from defects in design, material, and workmanship and shall operate in its intended environment in accordance with specifications, technical exhibits, drawings, and approved technical orders for the warranty period set forth. The warranty statement will be basically the same for the three different levels of warranty discussed in Chapter Three. The differences in the warranty levels will be accounted for in the technical exhibits cited or in the description of maintenance services to be provided. For example, where the contractor assumes full responsibility for all maintenance required by the equipment, such as in the depot, field support, and on-equipment warranty, it may be necessary to prepare a separate document that describes the services to be performed. This document is incorporated into the warranty statement by reference. (An outline of such a document, with explanatory comments, is provided in Appendix E.) For example, in a redundant system with high reliability, it may be desirable to have the Air Force perform preventive maintenance only and have the contractor perform all other maintenance. The basic warranty statement would define this arrangement in general terms, but the details would be spelled out in a separate document and incorporated into the warranty statement by reference.

7.1.1.2 Corrective Action

Under the depot warranty, failed equipment is returned to the contractor's repair facility and repaired by the contractor at no additional cost to the Government. A repair verification and test procedure is normally cited in the warranty provisions to verify that the failed item has been returned to servicable condition.

Under the depot and field support warranty the contractor is required to accomplish intermediate-level maintenance actions as well as depot-level repair. In this case, as well as under the depot, field, and on-equipment support warranty, detailed procedures may have to be spelled out in a separate document. For example, under the depot warranty Defense Contract Administrative Service (DCAS), or Air Force Plant Representative Personnel (AFPRO) will usually be available to verify that the required corrective action has been taken. However, in the other two cases, particularly for on-equipment maintenance, detailed procedures are required (1) to specify the corrective action required, (2) to indicate who will verify that it has been accomplished, and (3) to define the document or procedures for verification.

7.1.1.3 Unverified Failures

For the depot and field support warranties it is expected that a certain percent of the units removed by Air Force on-equipment maintenance personnel will "retest OK" (RTOK) when received at the contractor's repair facilities. Because of the cost incurred by the contractor in processing these units, the warranty provisions normally specify a maximum number (as a percent of total units returned) that the contractor will be obligated to process without additional reimbursement. Values between 10 and 30 percent are normally cited for electronic units. However, on occasion, where the competing contractors are given the incentive during development

to design extremely reliable built-in test equipment (BITE), the provisions could state that all units returned, including RTOKs, will be processed at no additional cost. This provision would tend to compensate the Air Force for the cost of returning good units if the BITE is not meeting specifications. It would also encourage the contractor to recommend improvements in his BITE design or failure verification procedures in the equipment technical orders. When a maximum number of RTOKs is specified, the provisions will include a stated dollar reimbursement the contractor is to be paid for processing each return above this number. For the depot, field, and on-equipment warranty, unverified failures would be entirely the contractor's responsibility. His own expense in processing RTOKs would encourage him to seek improvements.

7.1.1.4 Exclusions

Failures that are outside the contractor's control are normally excluded from warranty coverage. Examples are failures that result from fire, lightning, flood, and explosion. In addition, for the depot warranty and the depot and field support warranty, unauthorized maintenance or improper treatment could also be grounds for an exclusion. To preclude unauthorized maintenance, warranty seals are usually installed. Seal breakage coupled with other evidence of unauthorized maintenance normally excludes warranty coverage, and the item is repaired under a separate repair arrangement. The DCAS or AFPRO personnel normally certify that an item should be excluded under the depot or depot and field support warranties. For the depot, field, and on-equipment warranty the only exclusions permitted should be those due to acts of God, such as lightning or flood.

7.1.1.5 Warranty Coverage Period

In existing warranty contracts the period of warranty coverage has been stated in calendar time, operating time, or a combination of the two. The best method to use will depend on the particular application. For avionics equipment, which represents the majority of existing contracts, operating hours are particularly significant. For example, an avionics equipment may be operated only 40 hours per month out of a potential 720 hours. However, many items of ground electronic equipment operate 24 hours per day, 30 days per month, and they are "down" only for corrective or preventive maintenance. Equipments in this category include ground radar and navigational aids.

Table 7-1 describes a number of alternatives available for the warranty coverage period. Experience with existing warranty contracts indicates that when the warranty period begins upon Government acceptance of the equipment, using the fixed calendar period results in a waste of warranty coverage if the equipment is not put into operation soon after acceptance. For avionics equipment this situation occasionally occurs when there is a delay in retrofitting the equipment in the aircraft. When the warranty period for ground electronic equipment is being considered, the following factors are important:

- Installation - Some types of equipment will be placed in operation shortly after Government acceptance; however, other types (e.g.,

Table 7-1. WARRANTY COVERAGE ALTERNATIVES

Warranty Coverage	Advantages	Disadvantages
Fixed Calendar Period for All Units - All units are warranted for a fixed calendar time, and at the end of this time all units go off warranty. This means that the actual amount of warranty coverage for individual units will vary and that the user must gear up to take over maintenance at a single time.	Simplest to administer.	Units receive varying amounts of warranty coverage. Sudden shift from contractor to Air Force support could be disruptive. If units are not operated, value will not be received for prepaid warranty expense unless special adjustment provisions are made.
Fixed Calendar Period for Successive Production Lots - The warranty on all units within a production lot expires at a fixed time, but this time varies between production lots. This approach permits an essentially uniform amount of coverage for each unit but results in a situation in which some field units are under warranty and some are not. This may be administratively unacceptable, but it does ease the maintenance-takeover problem.	Permit incremental shift in support. Units receive more nearly equal warranty coverage.	Confusion may occur regarding disposition of failed unit after early warranty period(s) expire. If units are not operated, value will not be received for prepaid warranty expense unless special adjustment provisions are made.
Total Operating Hours, All Units - All units are under warranty until a total operating-hour level is reached. This type of coverage reduced uncertainty in pricing the warranty with respect to failure exposure, but the date of warranty termination is open-ended. Coverage on individual units will vary, and a means for measuring total operating hours must be established.	Assures that Air Force will receive full value for warranty cost.	More difficult to administer than fixed-calendar-time coverage. Contractor may be liable for extended period if operational usage is far below expectation.
Operate Hour or Calendar Time for Individual Units - The warranty on each unit expires after a specific number of operate hours and/or calendar time is reached. This type of coverage is similar to the 12,000-mile or twelve-month warranties associated with automobiles. This approach provides uniform coverage and provides the most information for warranty pricing, but it is administratively very cumbersome and might be appropriate only for warranty on such items as large, fixed ground equipment.	Provides contractor limit on time liability.	Requires individual item operate-time measurement. Administration most complex. Value may not be received if time expires. However, if an operate-time adjustment is added, this problem can be minimized.
Total Operate-Hour or Calendar-Time Coverage, All Units - This type of coverage provides for a single end time and it limits contractor liability. While organic-maintenance takeover is not completely specified, it is more predictable than just total operate-hour control.	Provides contractor limit on time liability.	Administration is complex. Value may not be received if time expires. However, if an operate-time adjustment is added, this problem can be minimized. Requires fleet operate-time measurement.

long-range radar equipment) may require an extensive period for installation at the using site. In this latter case it would be beneficial to have the warranty period start at the time installation is completed and the equipment is actually placed in operation.

- Quantity and Number of Site Locations - A large number of units creates administration problems if a common warranty end date is not used. For example, a mix of both warranted and nonwarranted units creates inventory control problems. For a relatively small number of units or using locations, staggered warranty end dates are more easily managed, and they more readily permit the warranty period to begin on individual equipments after installation is completed and to end following a stated calendar period. For large quantities of ground equipments, warranty administration will probably dictate a common end date.

- Operating Hours - As indicated above, many items of ground electronic equipment are operated 24 hours per day, 30 days per month, and are "down" only for preventive and corrective maintenance. For this reason most using commands and AFLC assume an operating time of 720 hours per month per installed unit in computing availability or MTBF and do not maintain separate operating logs. For many items of ground equipment, using 720 hours of operating time per month would be an adequate basis for warranty coverage as well. As a result, the warranty coverage period can be stated as a calendar period with an assumption of around-the-clock usage. For situations in which the equipment is used on a shift basis, an operating log or an elapsed-time indicator may be used.

- Equipment Reliability - The warranty period should be long enough to provide strong contractor incentive for achieving and maintaining acceptable reliability. As a minimum, the period should be long enough that at least several failures of each delivered equipment would be expected.

- Warranty Costs - On a per year basis, warranty costs should decrease as the warranty period increases since nonrecurring costs are amortized over a longer period and contractor "learning" takes place. This is especially true where the contractor is responsible for all maintenance and will probably invest in both physical and personnel resources to perform required activities. The model presented in Chapter Six is a means for evaluating the economic impact of alternate warranty periods.

7.1.1.6 Warranty Price

The contractor's price for the warranty, together with any associated options, is usually included in the contract cost schedule. The warranty itself will usually be an optional item; in addition, different warranty periods and the extent of warranty coverage could also be separate options. For example, the competitors could be asked to bid separate prices for a depot warranty and a depot and field support warranty.

7.1.1.7 Contract Price Adjustments

Contract price adjustments may be needed because of the following:

- Units being lost or damaged beyond repair. In the event a warranted unit is no longer subject to repair, an equitable adjustment should be made in the contract price.
- Operating-time adjustment. If the warranty coverage was based on operating time per calendar period, provisions should be made for adjusting the contract price for deviations from that originally agreed upon for pricing purposes. To minimize making small changes, a range such as $\pm$ 5 percent is often cited within which no adjustment will be made.
- Unverified failures. As stated in Subsection 7.1.1.3, the provisions normally specify a percent of the total returns that the contractor will process without a price adjustment. In the original bids the contractors should state this percent and the cost per unit for processing returns above the stated value. In the event the value is exceeded, the previously quoted price will provide a basis for the price adjustment.
- Exclusions. Items excluded from warranty repair due to mistreatment, seal breakage, etc., are usually repaired under a separate time-and-materials repair contract. However, on occasion, it may be desirable for administrative purposes to provide that exclusions which can be repaired under a stated dollar amount be repaired under the warranty contract.

The warranty provisions should indicate which of the above adjustments are applicable, the mechanism by which adjustments will be made, and the dates on which adjustments will be made.

7.1.2 Part II: Contractor Obligations

Part II of the agreement details many of the specific obligations the contractor must comply with to meet the terms of the warranty set forth in Part I. For a depot-level warranty it will normally be possible to define these obligations within the provisions; however, for the field support and on-equipment warranties it may be necessary to define these obligations in more detail. Appendix E outlines this procedure.

7.1.2.1 Warranty Markings and Seals

The contractor is obligated to provide suitable labels on the units to indicate that they are covered under warranty. Where the warranty period does not start until after installation, a final warranty label may be affixed in the field. For example, if the contractor actually installs the equipment, as may be the case for many ground equipments, one of his final actions will be to install the warranty labels and, if necessary, seals to preclude unauthorized maintenance. Alternatively, if the Government performs the installation, the contractor may provide a field representative to ensure that the installation was accomplished correctly in accordance with established

procedures. This field representative, after verifying correct installation, then affixes the warranty markings and seals.

7.1.2.2 Warranty Pipeline

The warranty provisions should specify both contractor and Government responsibilities relative to the repair pipeline. Provisions regarding contractor secure storage areas, repair turnaround time requirements, etc., will vary with the level of warranty. The following subsections describe alternative pipelines.

Depot Warranty

The prevailing depot warranty repair process for the Air Force, illustrated in Figure 7-1, comprises the following sequence of events:

1. A warranted unit suspected of failure is tested by military personnel at the using activity to verify the failure.
2. If the unit tests "good", it is put back into service or sent to supply as a ready-for-issue spare.
3. If the unit tests "bad", it is shipped, with appropriate data, to the contractor for repair.
4. The contractor receives the unit and verifies the failure and warranty coverage.
5. If the failure is not verified or is not covered by the warranty, corroboration by a Government representative is obtained. To cover exclusions, a separate repair contract is usually awarded to the contractor.
6. Repair of a covered failure is performed at no additional cost to the Government, and required data records are prepared.
7. The repaired unit is usually placed in a secure storeroom maintained by the contractor, pending disposition instructions from the Government.

Concurrently with step 3, a notice of failure is sent to the contractor's secure storage area and to the Item Manager (IM), with information copies to other parties as appropriate. A requisition is processed to the IM, who issues a Material Release Order (MRO) to the contractor. The MRO directs that a spare be sent to base supply. The spare will normally reach the base before the failed unit physically reaches the contractor. This shortens the equipment pipeline significantly and, for a given mission schedule, reduces the assets needed to support the schedule.

Depot and Field Support Warranty

Under the depot and field support warranty, the contractor provides field support at the intermediate level of maintenance in addition to depot-level repair. Figure 7-2 illustrates one possible pipeline arrangement

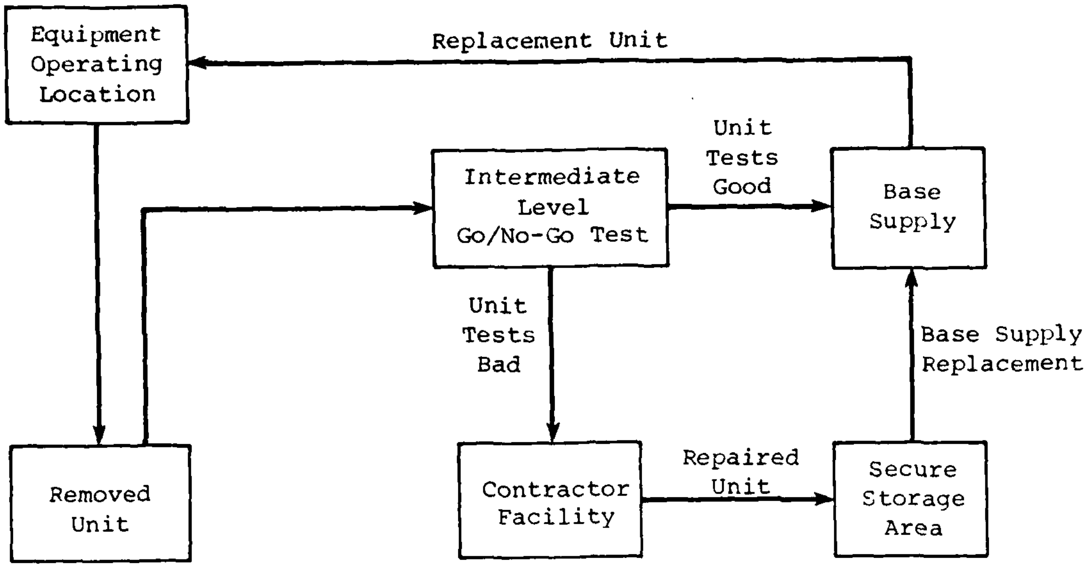
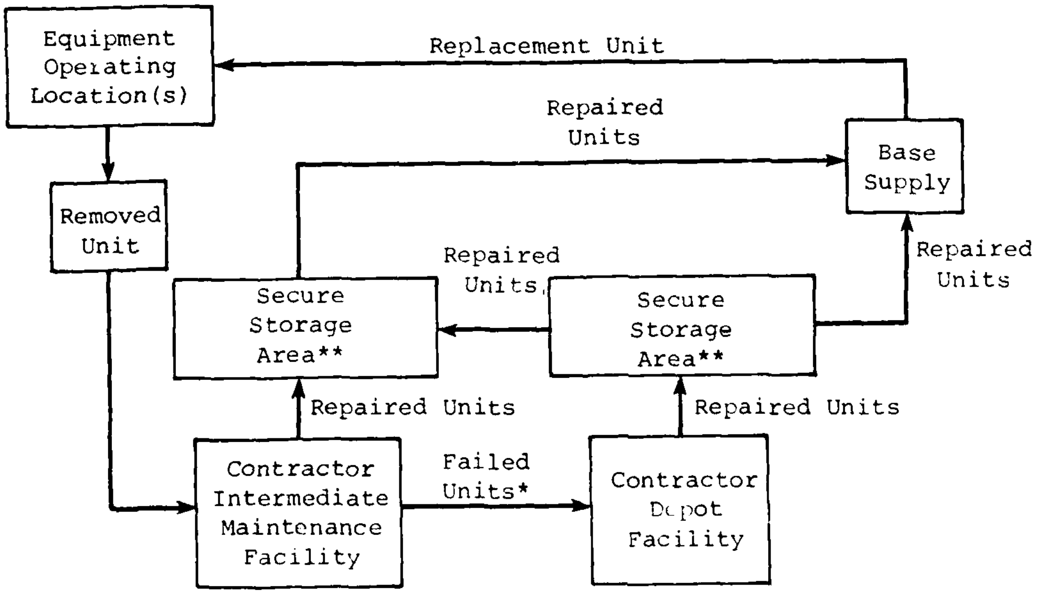


Figure 7-1. DEPOT WARRANTY PIPELINE UNDER SECURE STORAGE AREA CONCEPT



*Depending on repair requirements, some failures will be repaired at the contractor's intermediate facility while others will be returned to depot.
**Depending on the equipment and other requirements, a secure storage area may be required at both the depot and the intermediate facility.

Figure 7-2. DEPOT AND FIELD SUPPORT WARRANTY PIPELINE

for this type of warranty. It is anticipated that, to the maximum extent possible, all failures will be repaired by the contractor at the intermediate maintenance level and that only those requiring special depot facilities or extensive failure analysis will be sent to the depot. In the example shown in Figure 7-2 secure storage areas are shown at both contractor locations. This situation is most likely to occur where there are multiple sites. For example, if there are three different contractor intermediate maintenance sites, they will probably each stock certain replacement items. If one central contractor depot facility supports these sites, it will probably also stock these items. It is possible that the intermediate sites will stock at the module level while the central depot will stock both spare modules and subassemblies. The central depot could therefore ship replacement units to its intermediate sites or directly to a base supply.

Depot, Field, and On-Equipment Warranty

Under the depot, field, and on-equipment warranty, the repair pipeline is entirely under the contractor's control as long as he meets the contractual requirements for support of the on-equipment operations.

7.1.2.3 Repair Turnaround Time

For both the depot and depot and field support warranty pipelines described above, it is necessary to establish a maximum or average number of days for the contractor to complete repair and return the failed unit so base supply will be assured of having an adequate stock on hand to support on-equipment maintenance. For full contractor support, an alternative such as maximum duration of a single equipment downtime may be cited. Under these conditions the contractor sets his own repair turnaround time as long as he has adequate spares on hand to meet his maximum downtime requirement.

7.1.2.4 Turnaround-Time Penalty

To support the turnaround-time requirement for the depot and the depot with field support warranties it is necessary to provide a means of assuring compliance. Alternative plans that have been used include the following:

- Provision of additional spares. On the basis of an agreed-upon formula, the contractor provides additional spares on a consignment basis if there is an actual need for additional spares.
- Coverage Extension. Additional warranty coverage is provided (e.g., on a day-to-day basis) for units that are not repaired in the prescribed period.
- Monetary Payment. A monetary payment must be made on the basis of an established formula.

Of these two plans, the provision of additional spares is preferred since it accomplishes the objective of having sufficient spares to maintain the system. However, if the contractor no longer has the units in production,

the provision of additional spares may not be possible, at least in a reasonable time period. The latter two plans are considered alternatives to the first one. While they are not a substitute for additional spares, they do provide an incentive for the contractor to achieve the repair turnaround time.

Under the warranty in which the contractor is responsible for all maintenance, including on-equipment, a repair turnaround-time requirement more closely resembles an availability guarantee. The penalty is therefore assessed on the basis of this parameter rather than a repair turnaround time at the depot or intermediate level. If, for example, the parameter specified is that the equipment will never be down continuously for more than 1 hour, the contractor can be penalized financially for situations in which it is.

7.1.2.5 Engineering Change Proposals (ECPs)

By directly observing all field failures and being responsible for repair, the contractor can quickly identify failure patterns and institute appropriate corrective action through ECPs, which, by the terms of the warranty, are introduced at no cost to the Government. Class I ECPs will generally follow normal MIL-STD-480 procedures necessary for configuration control but, because of the no-cost feature, should be processed expeditiously. Changes not affecting form, fit, and function can be immediately introduced, with proper notification to the resident Government representative. To assure a standard configuration at warranty expiration, the contractor should be required to incorporate all approved ECPs into returned units and to provide modification kits for the remaining unmodified units. If the warranty period is long enough to result in multiple returns of each unit, the number of unmodified units at warranty expiration will probably be small. Otherwise, it may be advisable to negotiate for modification kits at warranty expiration so that ECP introduction will not be inhibited.

For non-ECP types of corrective action, the Government is kept informed through the data-requirements provision, which calls for corrective-action summary reports, as indicated in the following subsection.

7.1.2.6 Contractor Data Requirements

The contractor is required to develop a data system that can process information collected during the warranty program and can generate a series of periodic reports. For the depot-level warranty these reporting requirements have been standardized sufficiently that two Data Item Descriptions (DID) have been prepared by AFLC. The first of these DIDs is used in accumulating and analyzing failure data on the warranted items. The data permit the procurement activity to evaluate compliance with warranty provisions and to make the contract price adjustments described in Subsection 7.1.1.7. Detailed information contained in this DID is presented in Appendix F (DID-L-30321A).

The other type of data reported by the contractor pertains to supply and accounting data. When the contractor performs the repair and operates a bonded storeroom, supply transactions normally accomplished by an Air Force depot are now the responsibility of the contractor. For example, proper inventory management requires that the item manager be aware of the number of units in the storeroom, number in the repair cycle, etc. To facilitate this reporting, an AUTODIN terminal for communicating this type information is normally installed at the contractor's facility. Detailed data reporting requirements under this procedure are specified in Appendix G (DID-L-30320).

These DIDs, which were developed primarily for depot-level warranty, could be readily modified for the field support warranty and the field support and on-equipment warranty. The modifications required would be dependent on the specific equipment application. In most cases centralized reporting would be provided to the Air Force by the contractor's depot facility. Intermediate and on-equipment data would be collected by the depot and then summarized prior to delivery to the Air Force.

7.1.3 Part III: Government Obligations

7.1.3.1 Depot Warranty

Under a depot-level warranty the primary Government obligations are as follows:

- Accomplish preventive and on-equipment maintenance in accordance with applicable technical orders.
- Test all suspected failures in accordance with applicable technical orders to verify that the units have failed.
- Furnish test readings and failure-circumstance data to the contractor together with the failed unit.
- Furnish installation, removal, and operating-time data to the contractor.
- Ship units as failures occur to minimize batching; use approved shipping containers.
- Expeditiously process all contractor-submitted ECPs.
- Provide an AUTODIN terminal to the contractor if supply-transaction reporting is required.
- Provide Government Bill of Lading (GBL) shipping information to the contractor to authorize shipment at Government expense. (Experience has indicated that in the majority of cases it is less costly to the Government to pay shipping costs than it is to reimburse the contractor for costs incurred.)
- Provide Government representatives to verify data requirements, exclusions, and RTOKs, and to establish that corrective action has been completed.

7.1.3.2 Field Support and On-Equipment Warranties

Under field support and on-equipment warranties, it is necessary to account for ownership of spare parts, tools, test equipment, and other maintenance facilities, including space and utilities for field maintenance operations. Government obligations in these areas will frequently require detailed information such as that outlined in Appendix E.

7.2 GUARANTEES

As discussed in Chapter Four, Section 4.1.2, the incentives provided by a warranty alone may not be sufficient to achieve the specific operational capabilities desired. As a result, guarantees, either alone or in combination with a warranty, may be applied to give the contractor further incentive. Table 7-2 describes the various warranties, guarantees, and possible combinations. The following sections address each of the guarantees in more detail.

7.2.1 MTBF Guarantee

The MTBF guarantee is frequently used as an adjunct to a warranty, with the contractor guaranteeing that a stated MTBF will be achieved by the equipment in its operational environment. Where reliability growth is predicted, different MTBF values can be stated over different time periods. The basic guarantee requires that the equipment meet or exceed the stated value for each separate measurement period. The measurement periods used are typically in six-month or yearly increments.

The MTBF guarantee has generally been applied in conjunction with a depot-level warranty. The primary reason for combining the two is that it is difficult to have the contractor guarantee the equipment's MTBF unless he has control over the repair process. However, the Air Force has awarded at least one contract on ground radar equipment (TPX-42) wherein the contractor guarantees the equipment MTBF but the Air Force performs all maintenance, including depot-level repair. This type of arrangement (MTBF guarantee with no warranty repair) is most appropriately used for equipments that contain a number of discard-at-failure modules.

7.2.1.1 MTBF Definition and Measurement

The MTBF is usually defined as the total operating hours accumulated on all equipment during a measurement period divided by the number of verified failures during the same period. The method by which the operating hours are computed must be clearly stated. Possible methods include installing elapsed-time indicators on the equipment, maintaining special operating-time logs, or establishing an agreed upon estimate of a certain number of operating hours per day or per month. For many items of ground equipment it is assumed that the equipment is in continuous operation, and an operating time of 720 hours per month per equipment is used.

Type of Warranty	Type of Guarantee				
	None	Reliability - MTBF	Availability	[illegible]	[illegible] Support Type
Depot	1. Contractor provides depot-level maintenance.	Same as 1, plus contractor guarantees MTBF. If guarantee is not met, contractor provides spares either outright or on a [illegible] basis. Manditory [illegible] equipment may also be required.	Same as 1, plus guarantees availability [illegible] measurement method. If guarantee is not met, additional [illegible] provided at no cost to the Government or contract price is reduced. Mandatory [illegible] equipment may also be required.	Same as 1 [illegible] equipment [illegible] guaranteed [illegible] If guarantee is not met, penalty [illegible]	Same as 1, plus contractor guarantees that [illegible] equipment and intermediate maintenance support [illegible] a guaranteed amount. If [illegible] are exceeded, [illegible]
Depot and Field Support	[illegible] Contractor provides depot and intermediate or field support maintenance [illegible] warranty.	Same as [illegible] with guarantee arrangement as stated above.	Same as [illegible] with guarantee arrangement as stated above.	Same as [illegible] [illegible]	Same as [illegible] with guarantee [illegible]
Depot, Field, and On-Equipment	[illegible] Contractor provides all maintenance [illegible]	Same as [illegible] with guarantee arrangement as stated above.	Same as [illegible] with [illegible]	[illegible]	Not applicable.
None	Not applicable.	[illegible]	[illegible]	[illegible]	[illegible]

*[illegible]

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A failure definition must also be provided. When the guarantee is used with a warranty, failure can be defined as any unit that requires correction or replacement by the contractor at no cost to the Government under the warranty provisions. If the guarantee is used alone, an alternative definition must be used. One approach is to use malfunction codes that are consistent with the Air Force Maintenance Data Collection System defined in AFM 66-1. Basically, under this approach, any item counted as a failure for AFM66-1 purposes is also counted as a failure for purposes of MTBF guarantee computation. The method was used on the TPX-42 ground radar equipment procurement previously mentioned.

7.2.1.2 MTBF Guarantee Period

The time period for which the MTBF guarantee will be in effect must be stated. If the guarantee is applied in conjunction with a warranty, the same period may be used. However, to permit reliability to stabilize, it may be desirable to have the equipment operate for one year before measurement. It is usually provided that the contractor's obligation with respect to the guarantee will terminate when a specified number of consecutive measurement periods yield values that equal or exceed the largest specified value. Typically, two consecutive measurement periods are stated as the criteria for early termination.

7.2.1.3 Corrective Action Requirements

The provisions must state the corrective action the contractor must take, or what compensation the Government is to receive, in the event the guaranteed value is not achieved. Corrective actions, to be accomplished at no additional cost to the Government, might include (1) engineering analysis to determine causes of nonconforming units (2) corrective engineering design changes, and (3) modification of all units in the inventory. These corrective actions are more likely to be used when the guarantee is applied in combination with a depot level warranty. Under organic repair the contractor does not have the opportunity to perform failure analysis; therefore, organic repair and contractor corrective action requirements are not normally considered compatible.

7.2.1.4 Consignment and Ownership Spares

An additional compensation to the Government could be no-cost-to-the-Government spares either on a consignment basis or on an ownership-transfer basis. If warranty repair is in effect, the spares are provided on a consignment basis until the MTBF improves to the guaranteed values. If a warranty is not in effect, the contractor might be required to provide a quantity of spares sufficient to make up the pipeline deficit over the life of the system caused by the difference between the guaranteed MTBF and that actually achieved. Appendix D describes a method for determining the number of spares required. A formula is also provided to determine the number of consignment units to be returned by the Government when subsequent MTBF evaluations determine that the previously consigned quantity is excessive.

Time periods must also be stated for (1) the contractor to provide spares and (2) the Government, if required, to return spares provided on a consignment basis. It is further specified that in the event the contractor does not provide the spares when required, a daily liquidated damages penalty may be assessed up to a stated limit. Alternatively, if the Government does not return consignment spares when required, the contractor is paid a specified amount.

7.2.2 Availability Guarantee

As indicated in earlier chapters of this report, the availability guarantee has received relatively little use to date in DoD procurements. A primary reason is that several different factors can degrade availability and in many cases these factors may be outside the contractor's control. A greater degree of contractor control can be achieved by combining the guarantee with contractor maintenance under warranty.

7.2.2.1 Availability Definition and Measurement

The provisions must provide a definition of availability that is acceptable to both the contractor and the Government. Control parameters used in the definition could include operating hours per month, system downtime per month, and percent of shifts completed without failure. The preferred parameter will depend on the Government's objective and the specific equipment application. For example, in a flight simulator with on-equipment contractor maintenance the objective might be to complete two six-hour simulator training periods per day without interrupting equipment availability. The equipment would be available to the contractor 12 hours per day for maintenance, and he would guarantee its continued availability for the other 12 hours. For a ground radar the availability objective might be continuous 24-hour-per-day operation. In this case the need for preventive and occasional corrective maintenance would have to be recognized. Availability on a per unit or system basis could thus be defined on a monthly basis as

$$A = \frac{\text{Hours per month} - \text{PM} - \text{CM}}{\text{Hours per month}}$$

where

PM = equipment downtime for preventive maintenance

CM = equipment downtime for corrective maintenance

Hours per month = number of days in month times 24 hours

These terms would be summed for all operating units to yield the overall availability.

Separate provisions would address situations that could have an impact on the availability independently of the above equation. For example, if the contractor is performing on-equipment maintenance and the Government

is responsible for providing spares or test equipment used in the corrective maintenance, the provisions must allow for situations outside the contractor's control (e.g., unavailability of spares or test equipment needed for corrective maintenance). However, if the contractor is responsible for all maintenance and logistics support, including having the needed spares in place, no adjustments are required.

Redundant or fail-soft systems require additional detailed definition. In many cases the objective will be to ensure that total system failure does not occur. In these situations availability can be defined such that the contractor will not be penalized with respect to availability measurement unless total system failure occurs. Again, the definition of availability depends on the specific application. Availability achieved will normally be measured in accordance with special operating logs maintained for each operational unit.

7.2.2.2 Preventive and Corrective Maintenance

With an availability guarantee and contractor maintenance, the amount of downtime for preventive maintenance will normally be at the contractor's option depending on times agreed to for operational use. However, the circumstances under which corrective maintenance is required must be clearly defined. For some systems, where a failure occurs and the system is non-operational, the need for corrective maintenance will be obvious. However, for systems that can operate at a degraded performance level, the time at which the system ceases to be operationally available may be questionable. If operational specifications exist, they should be cited in the provisions in the same manner in which specifications are cited for failure definition. The time interval for corrective maintenance, as indicated in the above equation for measuring availability, will thus require start and stop times. (For example, in accordance with Technical Order XXXX, the need for CM started at 11 a.m., when the receiver sensitivity dropped below 50 dB; the CM period ended at 2:30 p.m., when the receiver sensitivity was restored). In most cases the equipment operator will be required to certify equipment availability by maintaining operating logs. He will also be required to notify the contractor of the need for corrective action. The operator will thus be performing some DCAS-type quality control functions.

7.2.2.3 Availability Guarantee Period

The period during which the availability guarantee will be in effect must be stated together with the different guarantee values, if there are any. For example, an availability growth comparable to an MTBF growth might be anticipated. The provisions could cite an availability of 90 percent during measurement period 1 (calendar time to be inserted), 95 percent during the period 2, etc.

7.2.2.4 Corrective Action and Remedies

The corrective action or remedies available to the Government if the guarantee is not met will depend to a large degree on whether or not the contractor performs the maintenance under warranty. For example, if the

contractor is performing the maintenance and the availability guarantee is not met, an equitable remedy is to reduce the contract price for the maintenance services. An agreed upon relationship might be stated -- e.g., for each availability precentage point below the guaranteed value, there is corresponding reduction in the fee for the maintenance services. The exact relationship would depend on the specific application. The provisions might further state that if the availability drops below a certain stated amount, additional corrective action is required. For example, if the guaranteed availability is 90 percent, a fee reduction is imposed for any achieved availability below this level. In addition, if the achieved availability is below 80 percent, further corrective action can be required, such as performing engineering analysis or modifying units.

If the Air Force is performing the on-equipment maintenance under an availability guarantee, different forms of remedies might be in order. For example, if the equipment was designed to yield a stated availability under specified conditions and this guaranteed availability is not being met, the contractor can be required, at no additional cost to the Government, to undertake engineering analysis to determine the causes of nonconformance. Possible causes are low equipment MTBF, faulty BITE, inadequate troubleshooting procedures in technical orders, inadequate or too frequent preventive maintenance, faulty test equipment, low proficiency, or poor training on the part of the technicians, or a combination of these factors. In some of these cases the cause of nonconformance might clearly be traced back to the contractor or to Air Force maintenance procedures, or to a combination of the two. In the event of nonconformance due to internal Air Force deficiencies, the provisions could permit the contractor to be reimbursed for the analysis performed. Otherwise, the contractor would not be reimbursed and, in addition, would be required to take appropriate corrective action on those nonconformance causes determined to be his responsibility.

It is recognized that such provisions could lead to disputes over contractor versus Government obligations. As previously stated, this is a disadvantage of attempting to apply an availability guarantee with Air Force maintenance. However, depending on the complexity of the on-equipment maintenance and the operational characteristics of the equipment, in some situations such an arrangement may be a viable alternative.

7.2.3 Maintainability Guarantee

Although maintainability parameters have been used in conjunction with logistics support cost guarantees, no known DoD applications in which maintainability has been used as a "stand alone" guarantee. However, a mean time to repair (MTTR) and a maximum corrective maintenance time (MAXCT) are frequently cited in the equipment design specification and demonstrated through verification tests.

Such parameters could be structured into an operational maintenance guarantee. As indicated in Table 7-1, the maintainability guarantee is

not normally combined with contractor on-equipment maintenance under a warranty. Instead, it finds its greatest potential where the Air Force is performing the on-site maintenance, with intermediate and depot maintenance performed under either organic or warranty conditions. An alternative is the situation in which the contractor installs the equipment and over a stated period demonstrates the on-site maintainability before the Air Force assumes on-site maintenance.

7.2.3.1 Definition and Measurement of Maintainability Guarantee

A definition of the maintainability parameter being guaranteed is required. Depending on the equipment and its operational and maintenance environment, the following parameters and associated definitions might be applicable.

- MTTR - the total corrective maintenance time during a measurement period divided by the total number of corrective maintenance actions during the same measurement period.
- False-Pull Rate - the number of maintenance actions in which no trouble is found divided by the total number of maintenance actions.
- False Return Rate - the number of returns for which no trouble is found divided by the total number of maintenance actions.
- Maximum corrective maintenance time MAXCT - the maximum time permitted to restore a system to operation. (This parameter would be significant for equipment such as an air defense radar, for which the maximum period of any single downtime may be more important than the number of times the system is down.)
- Total Organizational Maintenance Man-Hours - the total organizational maintenance workload at an individual equipment site or a combination of equipment sites, expressed as man-hours per year. (This parameter is used, for example, in the minimally attended radar sites currently under design.)

Any maintainability parameter defined must be consistent with the method to be employed to determine the achieved value. The normal AFM-66-1 maintenance data collection system can be used to collect the maintainability data required. It is being used, for example, in determining compliance with the MTBF guarantee on a ground radar unit. Conditions under which repair action is taken must also be specified. For example, the number of personnel on the maintenance crew should be cited, together with their proficiency levels and training status. Tools and test equipment needed should also be included.

7.2.3.2 Maintainability Guarantee Period

The period of the guarantee can be a stated calendar time, or it can be established on a demonstration-test basis as in a support-cost guarantee. If the potential for maintainability improvement exists, different time

periods reflecting improved performance levels can be specified. To control variations in maintenance actions due to differences in technician proficiency, motivation, etc., the achieved value can be measured on a demonstration-test basis.

7.2.3.3 Corrective Action and Remedies

The corrective action or remedy must be stated in relation to the maintainability parameter guaranteed. For example, if a mean time to repair has been specified, the contractor should be required to perform engineering analysis (1) to determine the causes of nonconformance and (2) to institute corrective actions such as redesigning BITE or revising troubleshooting procedures.

7.2.4 Cost Guarantee

7.2.4.1 Definition and Measurement

As indicated in Chapter Four, cost guarantees can take several forms depending on the specific costs of interest. Examples are life-cycle cost (LCC) and logistics support cost (LSC) guarantees, also called an LSC commitment (LSCC). These types of guarantees represent a commitment by the contractor that the cost to support the equipment in the long-term operational and maintenance environment will not exceed some "target" logistic support cost (TLSC). Some contracts contain provisions for award fees to the contractor if his equipment meets the objectives under verification tests. Alternatively, if the objectives are not met, the contractor may be obligated to correct equipment deficiencies until minimum acceptable cost objectives are achieved.

The model most frequenty used as a starting point is the AFLC Logistic Support Cost (LSC) model. It provides a method for computing expected design-related costs in various categories of logistics resource consumption but, like most other models, does not provide total life-cycle cost. Instead, it is intended to establish LSC figures of merit for various design alternatives and to establish baselines for contractual commitments. Thus the model is amenable to modifications, additions, and deletions to make it best represent the significant cost-driving factors when applied in specific situations. The model contains the ten cost categories indicated below (all except the spare-engine category are applicable to ground equipment):

- Cost of LRU Spares
- Cost of On-Equipment Maintenance
- Cost of Off-Equipment Maintenance
- Inventory Management Cost
- Cost of Support Equipment
- Cost of Personnel Training

- Cost of Management and Technical Data
- Cost of Facilities
- Cost of Fuel Consumption
- Cost of Spare Engines

Figure 7-3 shows the basis flow of activity in the application of the LSC concept. As part of the proposal activity associated with the transition from the validation phase to the engineering phase, the contractor is asked to supply a list of equipments and their associated logistic support costs. Such costs can be compiled through a logistics-support-cost model provided by the procuring activity. The list should encompass a large percentage of equipment support costs. It is expected that the list for a large weapon system would contain both CFE and GFE items, the latter included to provide maximum exposure of overall LCC.

The equipments on the list are rank-ordered in terms of their projected logistic support (highest to lowest). Beginning with the highest-logistic-support-cost equipments, items are selected until the aggregate cost of those selected equals at least some stated percentage of the total support of the original list. A value such as 50 percent represents a reasonable cut-off point, although some variation may be required depending on the nature of the system. Since the basic submission was requested to include both GFE and CFE, it is expected that the selected equipments will comprise both.

The weapon-system contractor has little control over GFE; therefore, it will be necessary to delete these equipments from the list although their impact on the total weapon system's support cost can be significant. As a lower limit, it is desirable to specify that the CFE items remaining on the list should constitute some minimum percentage -- for example, approximately 30 percent -- as a possible target value. The remaining CFE equipments become the control items to which the LSC commitment is applied.

If control items are selected prior to engineering validation, it may be in the interest of the user to consider warranty as an alternative control mechanism in lieu of LSC, with the choice being made later in the program.

It is expected that, with the more detailed information available during development, a more informed decision can be made. As shown in Figure 7-3, this course of action is advisable. However, it is important that the decision be made before long-lead production items are released to provide sufficient time for orderly maintenance planning regardless of the approach taken.

Because the contractor accepts added risk in the LSC, he is permitted to price his cost for the LSC on a fixed-price basis as a separate line item. If the LSC option is selected, the contractor's obligations include correction of deficiencies to bring the logistic cost within the prescribed

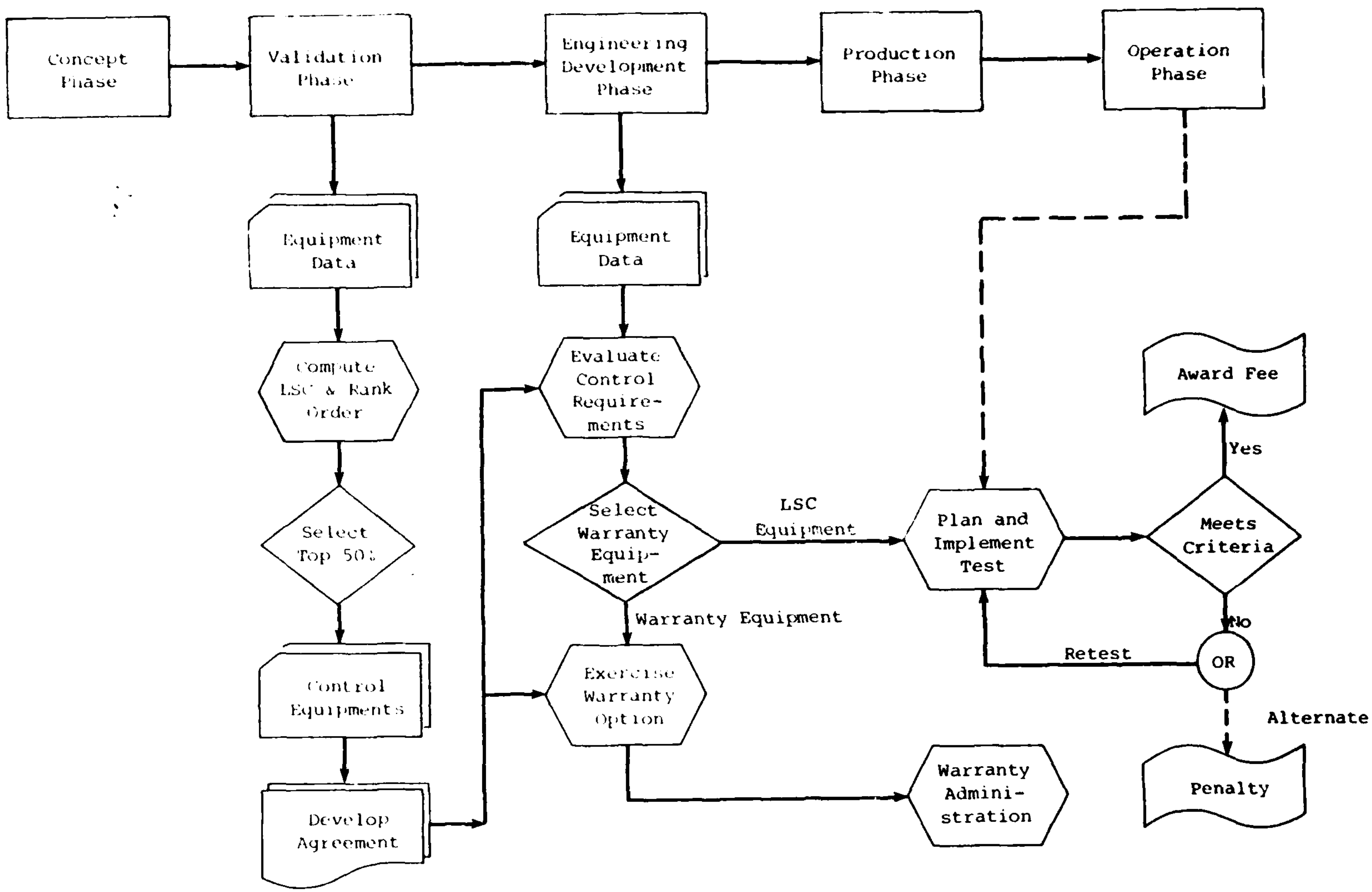

Figure 7-3. LSC COMMITMENT ACTIVITY FLOW

target. Deficiency correction may take the form of engineering change proposals or the provision of logistic assets. An alternative action is to invoke a contractual penalty clause.

LSC compliance is determined by the user's performing an operational test. The contractor is permitted to observe this test to assure his satisfaction with its conduct. From the test data, the measured logistic support cost (MLSC) is computed. If the MLSC is equal to or lower than the TLSC, an award fee is provided. In the event it is higher, corrective action or penalty payment, as outlined, is required.

A retest may be conducted if it is determined that it is necessary to judge whether compliance is met after corrective action has been undertaken. Usually, an award fee is not provided when the contractors meet the TLSC upon retest. Retesting may continue until compliance is demonstrated.

7.2.4.2 <u>General Requirements</u>

The general requirements usually associated with LSC provisions are as follows:

- Target Logistic Support Cost (TLSC). The definition and derivation of TLSC as a control parameter are provided, together with associated equations.
- Alternative Provision. The Government states its option to consider use of other control plans such as warranty or warranty/guarantee in lieu of LSC.
- Verification Test. The scope of the verification test is defined, together with responsibilities for test performance.
- Award Fee. The amount of the award fee is specified. Ideally, a formula for relating award fee to LSC savings should be specified.
- Correction of Deficiencies. The contractor's obligation in the event of failure to meet TLSC is noted.
- Deficiencies Definition. Types of deficiencies are defined, including:
  - Parametric Deficiency - the failure of the measured value of an LSC model parameter to meet the target value of that parameter.
  - Specific Deficiency - the identified causes of parametric deficiencies, e.g., circuit design, software, etc.

These definitions are provided to control the scope of corrective action in the case of a deficiency.

- Correction Approval. Actions required by the contractor to obtain Government approval for corrective action are detailed.
- Retest Provisions. The requirement to perform a retest in the event the TLSC is not met initially is noted.

- Scope of Commitment. The contractor's commitment under the provisions of this agreement continues until satisfactory compliance has been demonstrated.

7.2.4.3 Contractor Obligations

The contractor obligations associated with an LSC commitment are as follows:

- LSC Values. The contractor must provide values of TLSC for each equipment covered, together with the contractor cost quote for LSC coverage.
- Test Plan Review. The contractor receives the opportunity to review the Government's proposed test plan.
- Contractor Test Participation. The contractor is required to have a representative at, or available to, the test site to verify the authenticity of the test results.
- Corrective-Action Plan. If the MLSC fails to meet prescribed levels, the contractor must define his course of corrective action in a plan and submit it to the Government for review.
- Plan Implementation. Following approval, the contractor is required to implement the steps outlines in his corrective-action plan.
- Retest Plan Review. In the event a retest is required, the contractor must review the retest plan formulated by the Government.
- Contractor Retest Participation. As in the case of the initial test, the contractor is required to participate in all retest activity.

7.2.4.4 Government Obligations

The government obligations associated with an LSC commitment are as follows:

- TLSC Adjustment. Adjustments to the TLSC value may be made by the Government for a limited number of reasons, including Government-directed ECPs, force-structure or usage-rate changes, inflation factors, and Government-directed changes to maintenance concept.
- Corrective Action Review. The Government will review all proposed corrective actions.
- Test-Plan Preparation. The Government will prepare a test plan to verify the TLSC and provide the contractor opportunity to review and comment.
- Verification-Test Performance. The Government will provide the resources necessary for performing the verification test.
- MLSC Computation. On the basis of the test results, the Government will compute the MLSC.

- Award-Fee Determination. If the MLSC equals or is less than the TLSC, an award fee will be provided to the contractor in an amount to be determined by the Government.
- Contractor-Deficiency Notification. In the event the MLSC fails to meet required levels, the Government will officially notify the contractor that corrective action or penalty payment is required.
- Retest Determination. Depending on the nature of the deficiency, the Government will determine if a retest is required and will advise the contractor of its intent 30 days after receiving notification that the contractor has completed corrective action.
- Retest Continuation. The Government may elect to continue retest until compliance is demonstrated.

7.3 SUMMARY

This chapter has discussed provisions applicable to the three types of warranty presented in Chapter Three and the four types of guarantees discussed in Chapter Four. As indicated in Table 7-2, there are several possible combinations of these warranties-guarantees. It was noted that in some cases it may be necessary to supplement the warranty provisions by a separate statement of work if the contractor is providing full maintenance services under warranty. Appendix D provides specific language that may be used to construct a set of contractual warranty-guarantee provisions, and Appendix E outlines the factors that would have to be incorporated into the associated statement of work.

CHAPTER EIGHT

ADMINISTRATIVE AND DATA REQUIREMENTS

The success of a warranty-guarantee procurement will depend, in part, on proper Government management. Experience has shown that a critical factor is early coordination between the procuring organization, the Air Logistics Center within AFLC that will be managing the equipment after it is deployed, the DCAS organization that will be responsible for contract administration at the contractor's facility, and the using command(s). This chapter presents administrative procedures and data requirements that must be considered for successful implementation of *warranty-guarantee* plans.

8.1 WARRANTY-GUARANTEE ACTIVITIES

Table 8-1 lists the major activities that should be accomplished when warranty-guarantee plans are used; the following sections briefly describe these activities.

Table 8-1. MAJOR ACTIVITIES FOR IMPLEMENTING WARRANTY-GUARANTEE PROVISIONS

• Review contract provisions
• Verify using organizations and equipment deployment
• Review and update installation schedule
• Identify and monitor Air Force test and evaluation procedures
• Identify allowable Air Force maintenance actions
• Document failure-verification procedures
• Indoctrinate/train personnel
• Review contractor data plan

8.1.1 Review Contract Provisions

Prior to release of the RFP, all Government participants should review the provisions to ensure that the Government obligations specified can be

met and that a means exists, or can be developed, for determining the contractor's compliance with his obligations. A similar review should be made following contract award to identify any changes in the provisions that may have resulted from negotiations. This review is particularly important for the DCAS organization since the resident DCAS office cannot be identified until after the performing contractor is selected.

8.1.2 Verify Using Organizations and Equipment Deployment

Experience has shown that frequently after contract award additional users of the equipment are identified. For example, the Navy may decide that the equipment being procured will meet its requirements, or the Tactical Air Command may decide that equipment being procured for the Air Force Communication Service will meet its requirements. It is also possible that additional equipments will be procured for Foreign Military Sales. Any such changes that would affect the original understanding of deployment and usage of the equipment may require revisions to the warranty-guarantee provisions. Identification of such changes as soon as possible, particularly before equipment deliveries start, should reduce their impact.

8.1.3 Review and Update Installation Schedule

In several of the first warranty procurements there was a delay in installing the warranted equipment following delivery to the Government. As a result, a portion of the warranty coverage period was consumed while the items were in storage awaiting installation. It is therefore beneficial to review and update the installation schedule. If delay is expected, an attempt should be made to negotiate a corresponding change in the production schedule. If this is not feasible, an alternative is to have the contractor store the equipment in a secure storage area and postpone initiation of the warranty coverage. In any event, if review indicates installation delay, every feasible alternative to avoid the loss of warranty coverage should be explored.

8.1.4 Identify and Monitor Air Force Test and Evaluation Procedures

Many items of equipment will undergo an Initial Operational Test and Evaluation (IOT&E) prior to full scale production. These tests should be reviewed in relation to established maintenance, transportation, and inventory-management procedures. Depending on the types of tests being conducted, it may be necessary to exclude these items from warranty-guarantee coverage. However, if the circumstances permit, the existing procedures should be followed to the extent possible to determine any changes needed to accommodate the special conditions of the warranty-guarantee provisions. For example, during the IOT&E period on the ARN-118 TACAN, maintenance, supply, and transportation procedures being followed were closely monitored. This review identified several potential problem areas that would have degraded the Government's ability to fulfill its obligations under the warranty provisions. As a result, special handling procedures required to accommodate the warranted items were developed and implemented before production

units were delivered. When possible, similar monitoring of IOT&E tests in other programs should also be accomplished.

8.1.5 Identify Allowable Air Force Maintenance Actions

At the time of contract award the final equipment production configuration may not be finalized, nor is it likely that equipment maintenance technical orders (TOs) will have been outlined sufficiently to define allowable Air Force maintenance actions. As the design and equipment maintenance procedures stabilize, Air Force maintenance that may be taken without voiding the warranty should be identified and documented in the applicable TOs. These actions might include changing fuses, lights, filters, desiccant, etc. Preventive maintenance such as cleaning, lubricating, and calibrating should also be defined in the TOs. The contractor will normally prepare these procedures and submit them to the Government before incorporating them into the equipment manuals.

8.1.6 Document Failure-Verification Procedures

In many cases warranty-guarantee provisions will define a failure in terms of a specification that has not yet been prepared by the contractor or approved by the Government. Therefore, in the same manner as discussed above for allowable maintenance actions, after the failure-verification and repair procedures are defined in preliminary TOs, they should be reviewed carefully prior to Government approval. To the extent possible, the Government should use the same procedures and test equipment to verify a failure at the equipment location as those used by the contractor to verify failures at the repair facility. The purpose is to minimize the probability of "false pulls" and the number of good units returned to the contractor.

8.1.7 Indoctrinate/Train Personnel

8.1.7.1. Maintenance and Supply Personnel

Successful management of a warranty-guarantee program requires that maintenance and supply personnel handling the equipment be aware of the established procedures and comply with them. When an availability guarantee is being applied, it may also be necessary for the equipment operators to understand the guarantee conditions. For example, it may be necessary for the operator of a ground radar, in conjunction with the maintenance technician, to certify that the equipment is or is not available in accordance with the contractual definition of availability. Similarly, under full contractor warranty, which includes on-equipment maintenance, the equipment operator may be the appropriate individual to certify that the contractor has accomplished the required preventive and corrective maintenance. If several different items of equipment are included, such as at a remote radar site, one or more supervisory maintenance technicians may be assigned to the site to oversee contractor maintenance. They would fulfill the quality control function, ensuring that all maintenance was completed in accordance with approved procedures and that required maintenance data records were maintained.

8.1.7.2 DCAS Personnel

Administration of a warranty-guarantee contract at the contractor's repair facility will require some out-of-the-ordinary monitoring, record-keeping, decision making, and reporting. The following are the major DCAS responsibilities:

- Verify contractor receipt of items that have been damaged in shipment
- Verify presence and adequacy (or lack thereof) of failure-circumstance documentation
- Review contractor claims for exclusions, and authorize or deny the claim
- Monitor and verify contractor record-keeping, particularly the start and stop times for repair turnaround-time requirements
- Verify "retest OK" returns
- Monitor and verify custody transfer requirements, particularly that contractual requirements for the bonded storeroom operation are observed
- Identify problem areas and report them to the Procurement Contracting Officer (for example, using organizations not providing failure-circumstance documentation)

If the resident DCAS organization has not previously administered a warranty contract, training in these areas will be required. It will be necessary even for personnel experienced in warranty administration to review thoroughly the particular details of the contract to ensure an understanding of their responsibilities and ability to fulfill them.

8.1.8 Review Contractor Data Plan

It is necessary to ensure that the contractor has an adequate plan for collecting, analyzing, and reporting the warranty-related data required in the contract. These data permit the procurement organization to evaluate the effectiveness of the warranty and to make necessary contract price adjustments. Section 8.2 addresses these data requirements in more detail.

8.2 DATA REQUIREMENTS

8.2.1 Warranty and Reliability (MTBF) Guarantee

Proper administration of a warranty-guarantee program requires that data and information be acquired from the Air Force supply and maintenance activities, DCAS, and the contractor. Table 8-2 lists a number of data items used for administration of the warranty and reliability (MTBF) guarantee plan. (Data requirements for the other guarantee plans will be addressed in Section 8.2.2.)

Table 8-2. WARRANTY-GUARANTEE DATA ELEMENTS

Data Element	Data Source	Form
Initial Shipment Data		
1. Date Unit Shipped, Initial Delivery	DCAS	DD-25
2. Unit Serial Number	Contractor	Contractor Form
3. Unit Destination	DCAS	DD-250
4. Unit ETI Reading	Contractor	Contractor Form
User Support Data		
1. Date of Unit Receipt at Government Activity	AF Activity	GBL/DD1348
2. Date Unit Placed in Service	AF Activity	I/R Card*
3. Date Unit Removed from Service	AF Activity	I/R Card*
4. Reason for Removal	AF Activity	AFTO 349/350
5. Date Unit Shipped to Contractor	AF Activity	GBL/DD 1348
6. Date Unit Lost	AF Activity	AF Letter
7. Originating Field Activity	AF Activity	AFTO 349/350
8. Military Maintenance Man-Hours	AF Activity	AFTO 349/350
9. Number of Units Installed	AF Activity	AF Letter
Contractor Repair Data		
1. Date Unit Received by Contractor	DCAS/Contractor	GBL/DD 1348
2. Serial Number of Returned Unit	DCAS/Contractor	DD 1348
3. ETI Reading upon Receipt	DCAS/Contractor	DD 1348
4. Condition of Unit Based on Initial Inspection	DCAS/Contractor	DD 1348
5. Failed Item (to lowest identified level)	Contractor	Contractor Form
6. Probable Failure Mode and Cause	Contractor	Contractor Form
7. Action Taken to Repair	Contractor	Contractor Form
8. Man-Hours Expended in Repair, by Labor Category	Contractor	Contractor Form
9. Parts and Material Usage for Repair	Contractor	Contractor Form
10. Unit Test Results	DCAS/Contractor	Contractor Form
11. Date Repaired Unit Stored or Shipped	DCAS	DD 1348
12. Destination of Stored or Shipped Item	DCAS	DD 1348
13. ETI Reading at Shipment	DCAS/Contractor	DD 1348
14. Warranty-Coverage Applicability	DCAS	Contractor Form
15. Reason for Exclusion	DCAS	Contractor Form
Modification Action Data		
1. Date ECP Recommended	Contractor	Contractor Form
2. Date ECP Approved/Disapproved	Contractor	Contractor Form
3. Summary of Recommended ECPs	Contractor	Contractor Form
4. Serial Number Record of Unit Modification Status	Contractor	Contractor Form
Secure Storage Data		
1. Quantity of Units by Type at End of Each Month	Contractor	Contractor Form
2. Time Between Shipment Request and Shipment	Contractor	Contractor Form

*Installation/Removal Card.

Depending on the details of a particular procurement, some of the data elements listed in Table 8-2 may not be required; for example, the ETI and serial number elements may not be used in many ground equipments. In other cases additional data elements may be needed. However, the table does provide a guide for considering those data which may be necessary for administering a warranty-guarantee program. The five general sections of the table are discussed in the following subsections.

8.2.1.1 Initial-Shipment Data

Initial-shipment data are needed to determine the number of warranted items entering the inventory, the deployment location, and the warranty start period if the warranty begins upon Government acceptance. This information is needed for establishing the warranty coverage period and calculating statistics that depend on population size.

8.2.1.2 User Support Data

The operating commands will normally provide the data listed as user support data. These data are analyzed to measure reliability, maintainability, and other logistic parameters associated with the operating environment. The AFTO 349 is the Maintenance Data Collection Record, which the using-command maintenance technicians will complete to indicate the maintenance performed and the man-hours required. The AFTO 350 is a Reparable Item Processing Tag, also completed by the maintenance technician, which indicates the trouble experienced with the equipment. These two forms are returned with the failed equipment, and they constitute the failure circumstance data. Various formats have been used for the labels on the equipment to record the installation and removal data. Regardless of the format, the labels usually provide space for recording the following:

- Date of installation
- Date of removal
- Reason for removal
- ETI reading if applicable
- Modification status (configuration)

These entries summarize unit utilization and removal/failure information. When coupled with contractor shipping and receiving information, this information provides logistic flow times from contractor to installation and from removal to contractor.

8.2.1.3 Contractor Repair Data

The contractor repair data provide information on the frequency, type, and mode of failure experienced; turnaround time; and exclusions. This information is used for contract price adjustments, MTBF computations if applicable, and analysis pertaining to warranty extension versus transition to organic maintenance.

8.2.1.4 Modification Action Data

The modification action data pertain to contractor-initiated ECPs for reliability and maintainability improvement. This information is required to record configuration control and ensure that at the end of the warranty coverage all units are of the same configuration or modifications kits are provided. In addition, by correlating equipment performance achieved during specified periods with the modification status of the population, it may be possible to evaluate the effectiveness of modifications.

8.2.1.5 Secure Storage Data

Data on the secure storage of equipment will be required only for contracts under which the contractor maintains a bonded storeroom for repaired units. Data elements in this category are intended to provide information on contractor repair turnaround time, pipeline times, and the secure storage area's population.

8.2.2 Data for Other Forms of Warranty-Guarantee

Data requirements discussed in the preceding subsections pertain primarily to a depot level warranty, an MTBF guarantee, or a combination of the two. For other types of warranty-guarantee, some of these data elements may not be applicable or additional data may be needed. Some aspects of the data requirements were discussed in Sections 7.2.2 (Availability Guarantee) and 7.2.3 (Maintainability Guarantee). As noted therein, the data requirements will be dependent on the contractual definition of availability or maintainability and the measurement method cited. The standard AFM-66-1 maintenance data collection system can be used to collect data required for a maintainability guarantee. If, for example, the maintainability parameter being guaranteed is mean time to repair (MTTR), AFTO 349 (Maintenance Data Collection Record) would provide the required data. The following are some of the possible guarantee parameters, together with their measurement data sources:

Parameter	Data Source
Maintainability	
Mean time to repair	AFTO 349
Maximum corrective maintenance time	AFTO 349
Mean man-hours to repair	AFTO 349
"False pull" rate	AFTO 350
Availability	
Inherent	AFTO 349 and MTBF
Operational	Equipment Status Reports/ Special Operating Logs

If the contractor is performing maintenance and recording the data required to determine compliance with an availability or maintainability guarantee, it will be necessary for Air Force personnel to verify the data. In the majority of cases this should present no problem. For equipment requiring Air Force operators (for example, ground radars) they can either verify contractor-supplied data or maintain separate operating logs indicating equipment downtime. In other cases, even though a system is being maintained by contractor personnel, one or more Air Force personnel are normally on site. These are usually senior maintenance technicians who are responsible for verifying the contractor's quality control on both preventive and corrective maintenance. In addition, depending on the particular site, senior Air Force logistics specialists may also be available to provide liaison with the supporting Air Logistics Center. Thus, even when the contractor is maintaining the required data, verification by Air Force personnel will be possible and means will be available for determining contract compliance.

CHAPTER NINE

APPLICATION TO SAMPLE EQUIPMENT

This chapter demonstrates how the approaches presented in these guidelines would be applied to a sample equipment procurement. An attempt was made to use data from an actual procurement of ground TACAN transponders; however, because of a delay in the procurement cycle, several key documents and data elements were not available (e.g., the Statement of Work, system MTBF, and hardware and warranty bid prices). Nevertheless, to the extent possible, the sample application that follows is based on the ground TACAN transponder procurement. Where actual data were available, they were used; otherwise, assumptions were made to approximate the actual circumstances.

9.1 BACKGROUND AND CURRENT STATUS

TACAN is a short-range navigation system that provides distance and bearing data to aircraft. It consists of an airborne transmitter-receiver and a ground station. The ground station is triggered by receipt of the aircraft transmission and in turn transmits the station identifier and information to determine bearing and distance. The ground station equipment, illustrated in Figure 9-1, consists of four major assemblies: power supply, receiver-transmitter (transponder), station monitor, and antenna. In the past few years the Air Force modified the existing ground stations by installing new antennas and station monitor and control assemblies; however, the present transponders, many of which have been in service for 10 years or more, have not been replaced, and these now account for about 80 percent of all station failures. To correct this condition and to complete the upgrading of the ground TACAN systems, procurement action is now under way in the Air Force to buy approximately 140 transponders. Since two transponders are installed at each station (redundancy with automatic switchover if one fails), this purchase will accommodate 70 stations (spares are not taken into account).

A two-step procurement is planned, wherein two to four competitors will first submit technical proposals. Companies whose proposals are determined to be technically acceptable will then be requested to submit price proposals. The procuring activity plans to request bids on two separate warranty-guarantee options: (1) a reliability-improvement warranty (RIW) with an MTBF guarantee, and (2) an MTBF guarantee without the RIW. Although bid evaluation criteria have not been released, it is

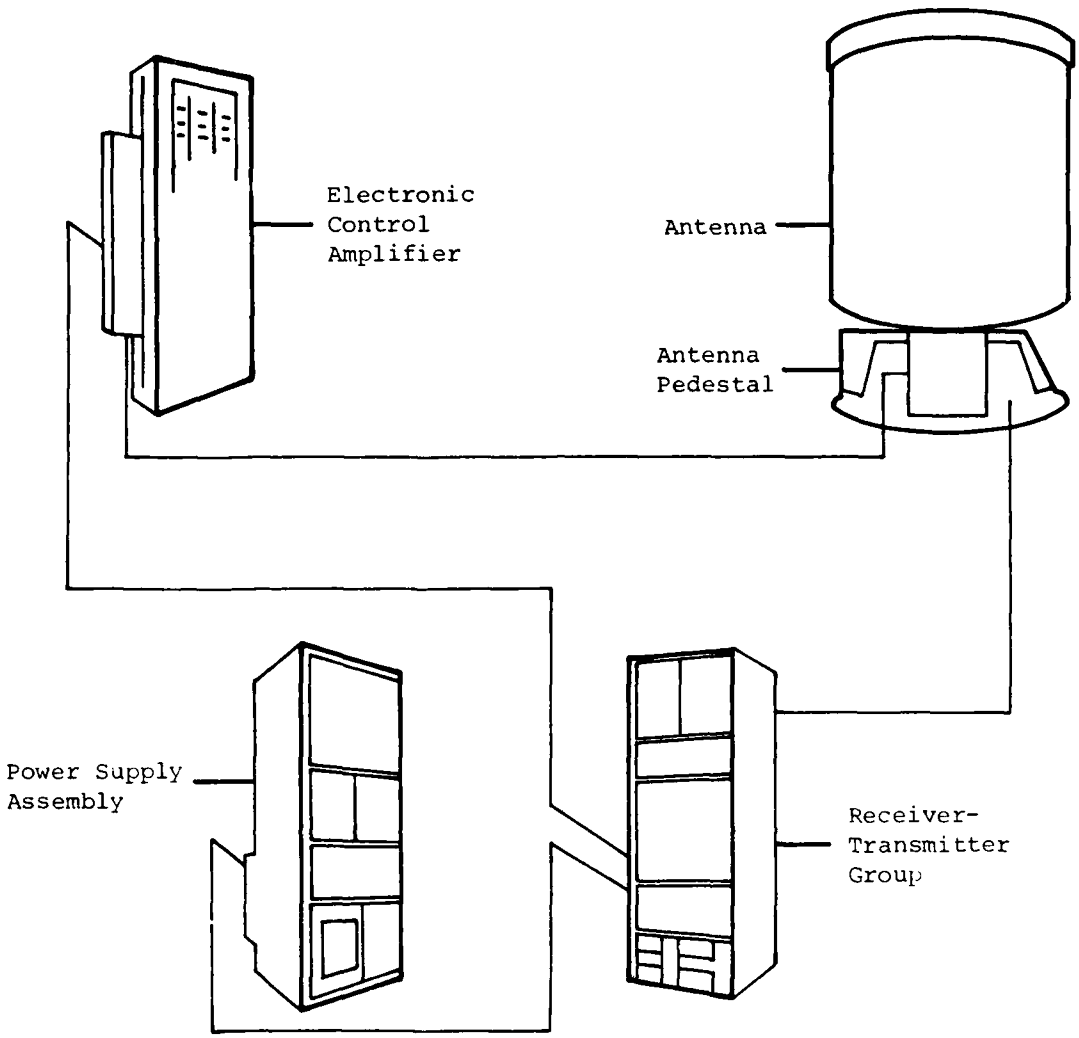

Figure 9-1. GENERAL DESCRIPTION OF GROUND TACAN EQUIPMENT

expected that the award will be based on total life-cycle costs (LCC). A copy of the model to be used in the LCC evaluation will be provided in the bid package. A minimum acceptable initial MTBF of approximately 2,500 to 3,000 hours will probably be cited, with bidders having the option of proposing MTBF growth to achieve a proposed guaranteed value at the end of a five-year warranty period.

The number of subassemblies and modules in the transponders will vary depending on how the manufacturer decides to package the equipment. Figure 9-2 illustrates the existing transponder, showing that it consists of six drawers containing subassemblies and modules. It is expected that the new transponders will have two to four drawers, which could contain a total of

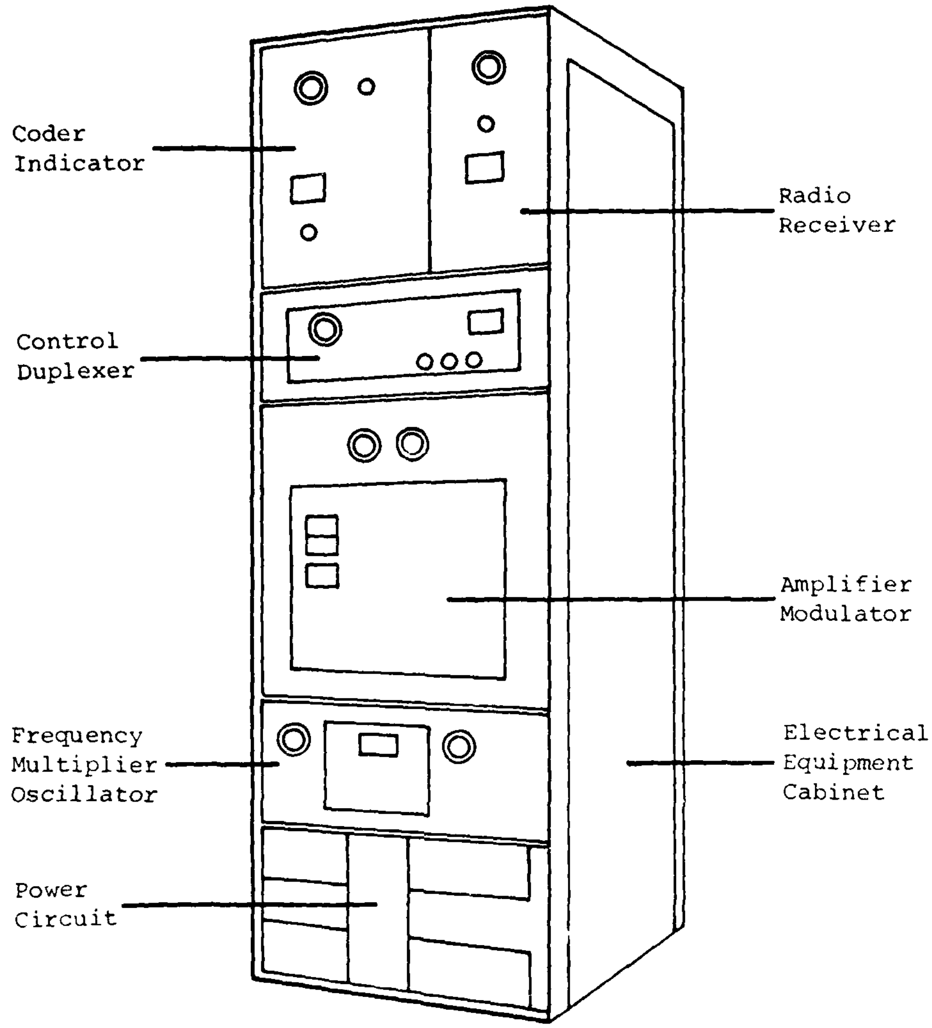

Figure 9-2. GROUND TACAN TRANSPONDER

80 to 100 separate modules. Again, depending on the packaging, the most probable maintenance scenario is that when a failure occurs, the station monitor and built-in test equipment will identify the faulty drawer and in many cases the faulty module. If a warranty is applied, it is expected that it will be at the module level. The technician will remove and replace the faulty module (in many instances a printed circuit board) and, after verifying its failure, return it directly to the manufacturer.

Under this arrangement, there will be no intermediate-level maintenance *per se*. On-equipment maintenance is performed at the station. Some of these stations are large enough to accommodate a workbench, which can be

considered to permit intermediate or off-equipment maintenance. At other stations there is insufficient space for even a workbench, and off-equipment maintenance may require transporting a suspected failure to a local base repair shop for bench check. In this case the base repair shop can be considered intermediate-level maintenance; however, it is very unlikely that whole drawers or subassemblies will be removed and replaced and then sent to an intermediate shop for replacement of faulty modules.

9.2 WARRANTY-GUARANTEE APPLICABILITY

9.2.1 Depot, Field Support, and On-Equipment Warranty

With an equipment deployment of only one station (two transponders) at any site, there would not be sufficient workload to justify full contractor maintenance. Even if the contractor undertook full maintenance of all the TACAN station equipment, rather than the transponders alone, the workload would still not provide economic justification for resident contractor maintenance personnel. An alternative might be to have the contractor perform maintenance, under a service contract, on additional base navigational-aid equipment, such as instrument landing system (ILS) and radar approach control (RAPCON) equipment. Base communications equipment could also be added. However, in this arrangement the maintenance services on the other equipment would far overshadow that on the transponders, and these services should be considered independently of TACAN warranty maintenance.

Another alternative would be to have full contractor maintenance and to consider each station a remote location. In this scenario, the Air Force would perform preventive maintenance only. When one transponder failed and the station switched over to the second transponder, the contractor would be notified. He would be given a certain time limit (hours or days) to reach the site and repair the failed transponder. This might be a viable alternative if the Air Force did not already have maintenance personnel at the sites to maintain other navigational equipment. If a ground TACAN system MTBF of 2,000 hours and 8,760 operating hours per year (365 days/year × 24 hours/day) were assumed, then, on the average, only 4.38 failures per installation per year would be expected. The workload associated with these few failures can usually be absorbed by the workforce maintaining the other navigational aid equipment. Therefore, for full contractor maintenance to be a viable economic option, it would be necessary to make major workload shifts that are independent of warranty considerations on the TACAN transponders.

9.2.2 Depot and Field Support Warranty

As previously noted, it is expected that little, if any, field support or intermediate-level maintenance will be required for the transponders. The most probable support will be to remove and replace modules and, following failure verification, return them to a depot for repair. Under this support concept the depot and field support warranty would not be considered.

9.2.3 Depot Warranty With MTBF Guarantee

The equipment meets most of the application criteria discussed in Chapter Five for a depot warranty with MTBF guarantee. However, the following criteria merit comment:

- Production Period - Although the transponder delivery schedule has not been established, it is assumed that deliveries would be made over a period of approximately three years. This would permit warranty repairs to be interleaved with production activity. ECPs could be introduced into the population more quickly, and consignment spares, if required, would be less expensive. If the production period were less than three years, these benefits would be reduced and a warranty would become less attractive.
- Elapsed-Time Indicator (ETI) - An ETI could be installed on the transponder and install-remove dates and ETI readings recorded for each module. However, with the large quantity of modules installed, the record-keeping for each module would be impractical. It would be more economical from a warranty-administration standpoint to assume 24-hour-per-day operation.
- MTBF Computation - As indicated above, the actual recording of operating time on each module would be impractical from a warranty-administration standpoint. Instead, the Air Force could provide operating-time information on each TACAN station. (This information is currently being maintained by AFCS for Equipment Status Reports.) The total operating time for all the equipments would be the sum of the individual site times, and MTBF would then be computed as shown in Part V of Appendix D.

9.2.4 MTBF Guarantee Without Depot Warranty

As indicated in Chapter Seven, there is only one known procurement that includes an MTBF guarantee under which the contractor does not perform warranty repair -- i.e., 20 modules in the TPX-42 ground radar Programmable Indicator Data Processor (PIDP) equipment. (Eight of the 20 are discard-at-failure modules.) The contract provisions call for testing at least 40 PIDPs at eight different operational sites over a one-year period. At the conclusion of the test period the MTBF will be computed on each individual module. If the computed MTBF is less than 85 percent of that guaranteed, the contractor must provide (at no additional cost and with ownership passing to the Government) those additional pipeline spares needed for a planned 10-year life cycle. The quantity of additional spares will be determined by computing the spares first from the actual guaranteed value and then from the achieved value. Where the achieved MTBF results in a higher quantity of spares (because the MTBF is less than 85 percent of that guaranteed), the contractor must make up the difference in spares required. This difference will be based on the actual guaranteed MTBF, not the 85 percent value. Initial PIDP units produced are currently undergoing initial operational test and evaluation (IOT&E); however, it will be some time before the MTBF computational tests begin. Therefore, the results of this procurement depend on additional testing.

Although circumstances will vary with individual procurements, in most cases the contractor's risk will be greater under an MTBF guarantee without a depot warranty than it will be where he is also performing warranty repairs. Under warranty repair he has the opportunity to perform failure analysis and institute corrective action during the guarantee period. However, under the MTBF guarantee alone, the contractor must design, produce, and deliver equipment that immediately meets the guarantee requirements; there is no opportunity for reliability growth to the guaranteed value.

The degree of contractor risk will be dependent on the particular equipment circumstances; his willingness to accept the risk will be determined in part by the competitive situation and the total dollar value of the production contract. For example, in the PIDP procurement the total production was large enough to make the procurement attractive to bidders, and competition was keen. In addition, the winning bidder had extensive experience with earlier versions of similar equipment. The risk involved with the MTBF guarantee was therefore considered acceptable to the contractor.

The transponder procurement may be comparable to the PIDP procurement. At least three companies are expected to compete for the award; they are all considered to have proven capability in the TACAN transponder area and are currently either producing or will be producing comparable equipment under other DoD or FAA contracts. The equipment meets the major criteria for a reliability guarantee that were discussed in Chapter Five.

9.2.5 <u>Applicability of Other Forms of Guarantee</u>

The other forms of guarantee (availability, maintainability, and cost) are considered less applicable to the transponder than the reliability guarantee. For example, because of redundancy, rapid restoration time is not of critical importance, particularly with the relatively high MTBFs expected. TACAN availability should be high because of the expected reliability coupled with redundancy. In addition, the availability of the TACAN is not as important for operational or safety purposes as the availability of other items of navigational-aid equipment such as an instrument landing systems or radar approach control systems. For essentially the same reasons, many aspects of a maintainability guarantee are not applicable. For example, an acceptable MTTR should be obtainable; this, coupled with redundancy, should be adequate for operational requirements, and a guarantee should be unnecessary. If the equipment were part of a nonredundant system and operational requirements dictated minimum downtime, a maintainability guarantee would merit further consideration.

The major difference between the logistic support cost (LSC) guarantee and the MTBF guarantee is the number of parameters considered. Under the reliability guarantee the only parameter is MTBF, while under the LSC guarantee a wide range of parameters could be included. It is anticipated that many of these parameters will have little impact on the life-cycle costs of the transponders. For example, peculiar AGE, test equipment manuals, and extensive training are not considered necessary. As will be shown in Section 9.3, the major drivers of the LCC are the acquisition costs and initial system MTBF.

9.3 MODEL APPLICATION

On the basis of the discussion in Section 9.2, we will assume that a depot-level warranty with MTBF guarantee is being considered and we will proceed to evaluate the economics of this approach.

Chapter Six addressed the economic aspects of warranty-guarantee analysis. Appendix A documents the model developed and provides detailed information on its use. The same application of the model discussed in this chapter is also discussed in more detail in Appendix A. The additional detail includes methods for inputting the data and performing sensitivity analysis. This section will highlight the use of the model in analyzing the transponder procurement.

9.3.1 Assumptions on Model Inputs

As indicated at the beginning of this chapter, several data elements pertaining to the TACAN procurement were not available. Therefore, we made assumptions that we believed to approximate these data. Highlights of our input data and assumptions are as follows (several of these data elements are subsequently varied to indicate the sensitivity of the outcome in the event our original assumptions were incorrect):

- A total of 140 transponders are procured for installation over a three-year period. Fifty sites have one ground station, and ten sites have two stations, one of which is at the Air Force Base and another at an adjacent test range. Fifty-five sites operate 24 hours per day, and five sites operate 12 hours per day.
- The initial MTBF is 2,500 hours. For reliability growth, the maximum growth factor is 75 percent. Further, under organic maintenance a 10 percent improvement in reliability is expected between the first 1,000 and 50,000 hours of operations, and under warranty a 20 percent improvement is expected. (These values are subsequently varied to indicate their impact on the LCC output.)
- The life-cycle period is 10 years, and a 10 percent discount rate is used.
- Unit acquisition cost per transponder is $100,000. Depot AGE for organic maintenance costs $100,000, and base AGE costs $15,000 per base under organic and $5,000 per base under warranty. The annual base AGE support cost factor is 7 percent per year, and the annual depot AGE support cost factor is 10 percent per year.
- Warranty prices are estimated by using the warranty pricing algorithm described in Section 6.3.3 of Chapter Six. A risk factor of 5 percent per year and a profit factor of 12 percent are established. (The risk factor is subsequently varied to indicate its impact; the warranty price is also varied as possible bid values in lieu of computing the price.)

- Under warranty the contractor is expected to incur an initial fixed cost of $250,000 and yearly costs of $50,000 for warranty report preparation.
- The equipment must meet a guaranteed MTBF of 3,500 hours by the end of the fifth year. (This value and the initial MTBF are subsequently varied to determine the impact of these parameters.)
- Under warranty, the Government incurs a yearly cost of $30,000 for warranty administration; at transition a cost of $50,000 is incurred to cover expenses associated with the conversion from warranty to organic maintenance.

9.3.2 Model Output

Table 9-1 presents a partial output of the LCC model. The entire output is explained in detail in Appendix A. This section highlights outputs of the model used in the analysis. Table 9-1 lists the total ten-year discounted life-cycle costs under organic maintenance and then under warranty for each of the warranty periods. Also printed are the associated warranty savings/loss, warranty price, and average MTBF. For example, the 5.00-year line means a five-year warranty followed by five years of organic maintenance. The LCC for this warranty/organic arrangement is $18,067,538, which represents a saving of $421,217 from the full 10-year organic LCC of $18,488,754. Included in the warranty LCC is the computed warranty price of $831,849. The average MTBF for the full ten year period is 3,518.

Table 9-1. ORGANIC AND WARRANTY LCC - INITIAL MTBF: 2,500 HOURS

TOTAL ORGANIC LCC = $ 18488754.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	18500430.	-11676.	35[illegible].	3288.
2.00	18328300.	160455.	455793.	3406.
3.00	18238145.	250609.	575364.	3468.
4.00	18136934.	351821.	703139.	3500.
5.00	18067538.	421217.	831849.	3518.
6.00	18017403.	471351.	962122.	3529.
7.00	17986984.	501770.	1094427.	3535.
8.00	17975068.	513686.	1229176.	3539.
9.00	17979586.	509168.	1366749.	3541.
10.00	17998353.	490402.	1507516.	3541.

Table 9-2 presents an additional output of the model showing the life-cycle cost for full organic maintenance, as well as five-year warranty followed by five years of organic maintenance. This output divides the total LCC into the categories discussed in Chapter Six. The MTBF Guarantee line is shown as zero since for this example the 3,500-hour MTBFG was met. Had it not been met, the value of the consignment spares would have been shown on this line. To demonstrate the consignment-spares aspect, the interactive feature was exercised and the initial MTBF was reduced from 2,500

Table 9-2. LCC COST CATEGORIES FOR FIVE-YEAR WARRANTY - INITIAL MTBF: 2,500 HOURS

	ORGANIC	WRNTY+ORG
ACQUISITION	14000000.	14000000.
INITIAL SPARING	330000.	280000.
REPLENISHMENT SPARES	74111.	52919.
CORRECTIVE MAINTENANCE	591507.	265072.
PREVENTIVE MAINTENANCE	742032.	742032.
WARRANTY PRICE		831849.
AGE	1000000.	734645.
AGE SUPPORT	470447.	263105.
TRAINING	350654.	269521.
DATA	300000.	205230.
INVENTORY MANAGEMENT	530003.	263926.
MTBF GUARANTEE		0.
OTHER	50000.	158639.
TOTAL	18488754.	18067538.

to 1,250 hours. Tables 9-3 and 9-4 provide partial outputs for this revision. The computed five-year warranty price increases to $1,022,182, the total organic LCC increases to $19,263,984, and the five-year warranty followed by five years of organic now results in a saving of $1,425,317. Table 9-4 indicates that this increase in savings over the previous case is primarily due to the MTBF Guarantee value (consignment spares) of $845,628. (The negative sign on this line indicates that it decreases the LCC.)

Table 9-3. ORGANIC AND WARRANTY LCC - INITIAL MTBF: 1,250 HOURS

TOTAL ORGANIC LCC = $ 19263984.

WRNTY YRS.	WRNTY LCC	SAVINGS LCC	WRNTY PRICE	AVG.MTBF
1.00	19202914.	61071.	364935.	1644.
2.00	1899594[illegible].	[illegible]	490514.	1703.
3.00	18993361.	[illegible]	657510.	1734.
4.00	18768019.	[illegible]	839638.	1750.
5.00	17838667.	1425317.	1022182.	1759.
6.00	[illegible]	[illegible]	1206222.	1764.
7.00	17761294.	[illegible]	[illegible]	1768.
8.00	[illegible]	[illegible]	1581722.	1769.
9.00	[illegible]	[illegible]	[illegible]	1770.
10.00	[illegible]	[illegible]	1971039.	1771.

9.3.3 Sensitivity Analysis

Returning to Table 9-1, we note that on the basis of the data we have inputted, the LCC saving for a five-year warranty is only $421,217 or 2.24 percent of the organic LCC. As indicated at the beginning of this chapter, it was necessary to make assumptions for various input parameters. For example, we assumed that under warranty the MTBF growth would be [illegible] percent

Table 9-4. LCC COST CATEGORIES FOR FIVE-YEAR WARRANTY - INITIAL MTBF: 1,250 HOURS

	ORGANIC	WRNTY/ORG
ACQUISITION	14000000.	14000000.
INITIAL SPARING	438000.	384543.
REPLENISHMENT SPARES	149834.	107825.
CORRECTIVE MAINTENANCE	1182015.	530144.
PREVENTIVE MAINTENANCE	742032.	742032.
WARRANTY PRICE		1022182.
AGE	1000000.	734645.
AGE SUPPORT	470447.	263705.
TRAINING	350654.	269521.
DATA	300000.	205230.
INVENTORY MANAGEMENT	580063.	263926.
MTBF GUARANTEE		-345628.
OTHER	50000.	160542.
TOTAL	19263984.	17838667.

and that under organic maintenance it would be 10 percent. What if these values were, respectively, 25 percent and 10 percent, or 15 percent and 10 percent? Again, the interactive feature of the model permits such an evaluation. These and several other input parameters were varied to determine how the outcome would be changed under different input circumstances. Rather than list the outputs in tables, we plotted the results in Figures 9-3 through 9-8.

Figure 9-3 indicates, as a function of initial MTBFs, the ten-year LCC for the full organic alternative versus a five-year warranty followed by five years of organic maintenance. The cost curves go in opposite directions for any initial MTBFs less than 2,500 hours. Under warranty for these initial MTBFs, the MTBFG value is not met and consignment spares are provided. Above 2,500 hours the two curves are approximately parallel, with the warranty/organic LCC being approximately $420,000 less than the organic LCC at the 2500 hour point. A slightly different presentation of initial MTBF sensitivity is given in Figure 9-4, where the savings/loss is shown for different warranty periods as a function of initial MTBF. The steep rise between the fourth and fifth year for an initial MTBF of 2,[illegible] hours is due to the provision of consignment spares. This figure clearly demonstrates how the MTBF guarantee protects against a low initial MTBF. Figures 9-5 and 9-6 address the sensitivity [illegible] MTBF growth under various combinations of warranty [illegible] reliability growth. In Figure [illegible]-7, the warranty growth [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

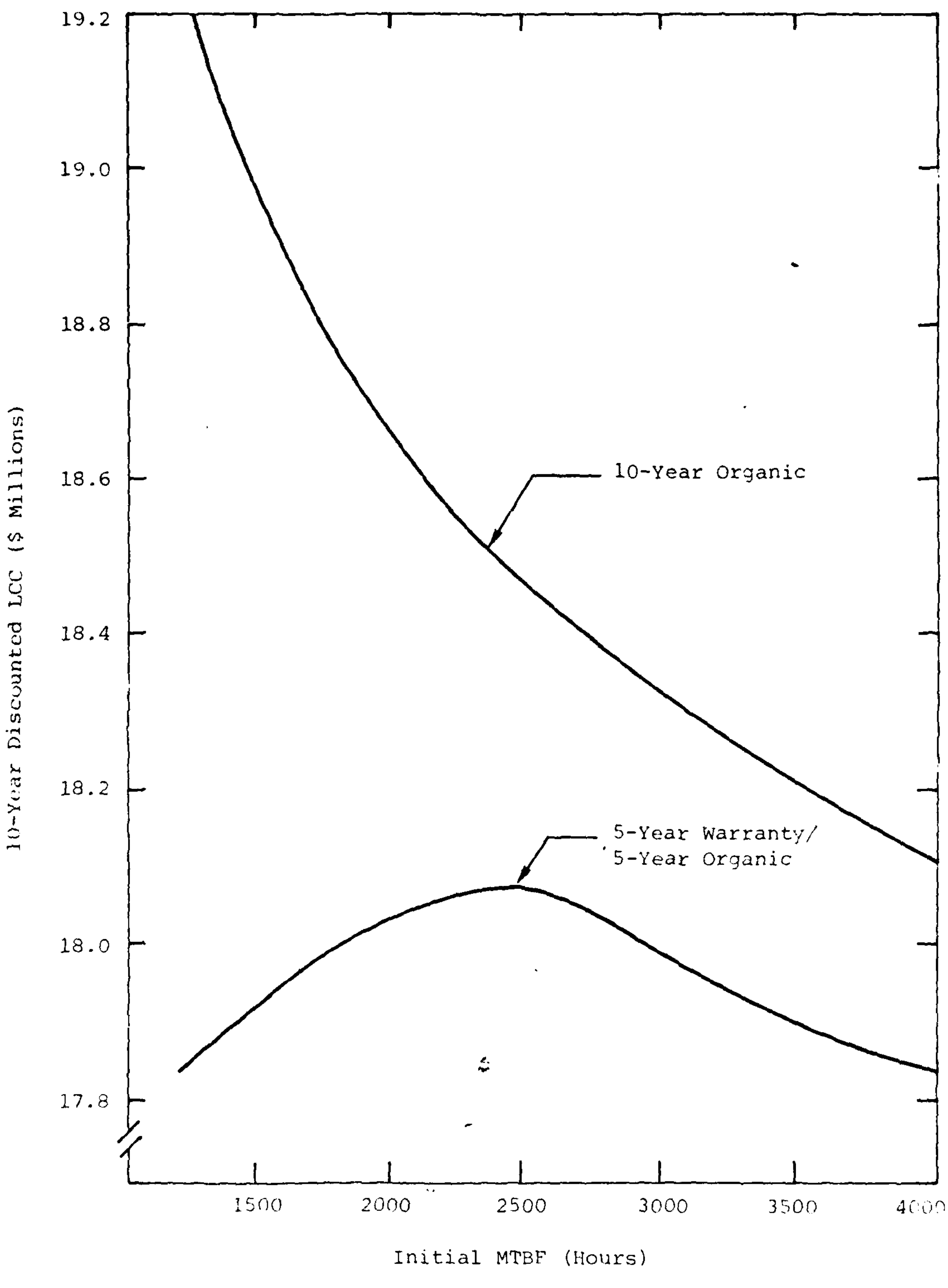

Figure 9-3. ORGANIC VERSUS WARRANTY/ORGANIC LCC AS A FUNCTION OF INITIAL MTBF (MTBF GUARANTEE: 3,500 HOURS)

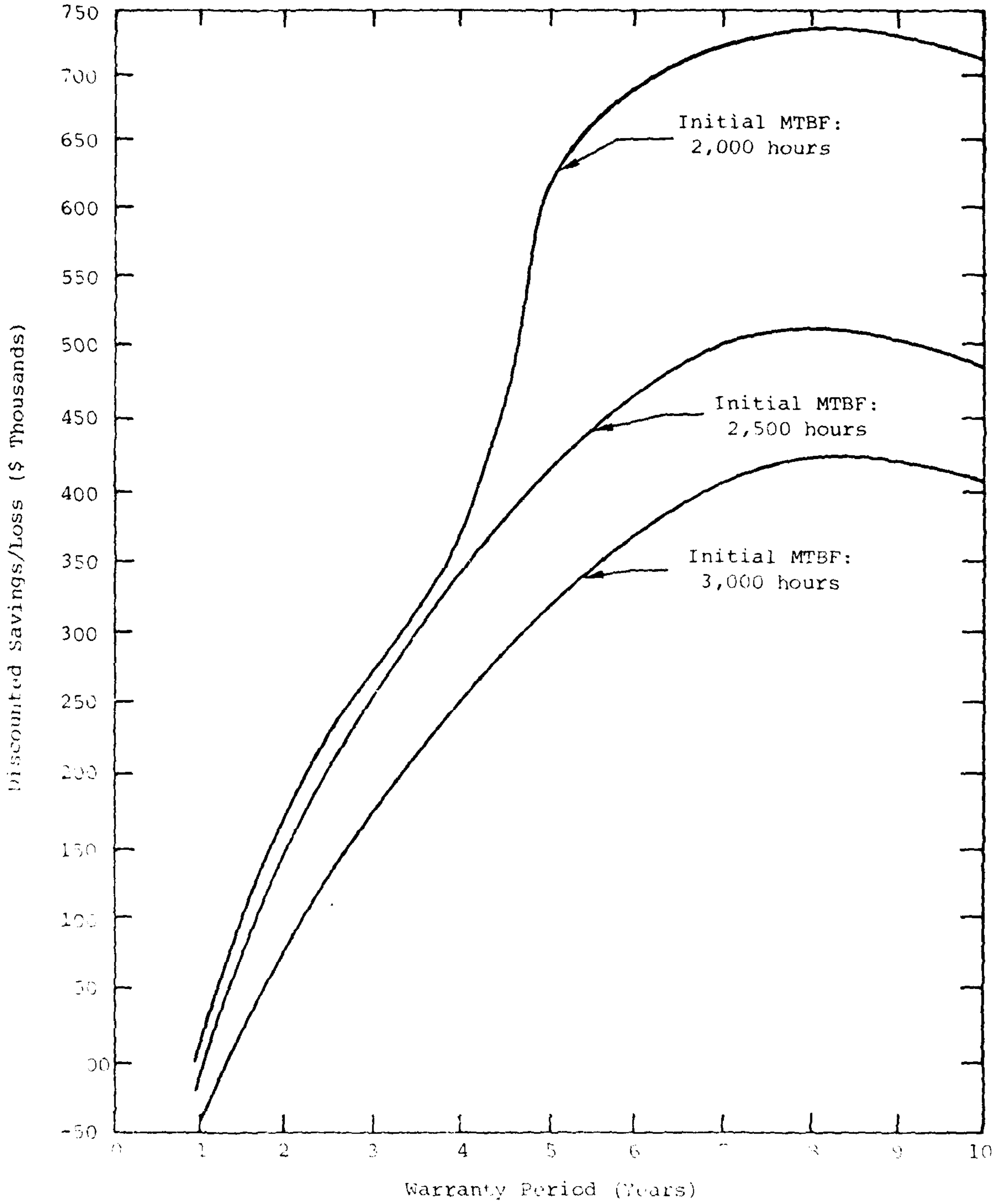

Figure 9-4. DISCOUNTED SAVINGS/LOSS BY WARRANTY PERIODS AS A FUNCTION OF INITIAL MTBF (MTBF GUARANTEE: 3,500 HOURS)

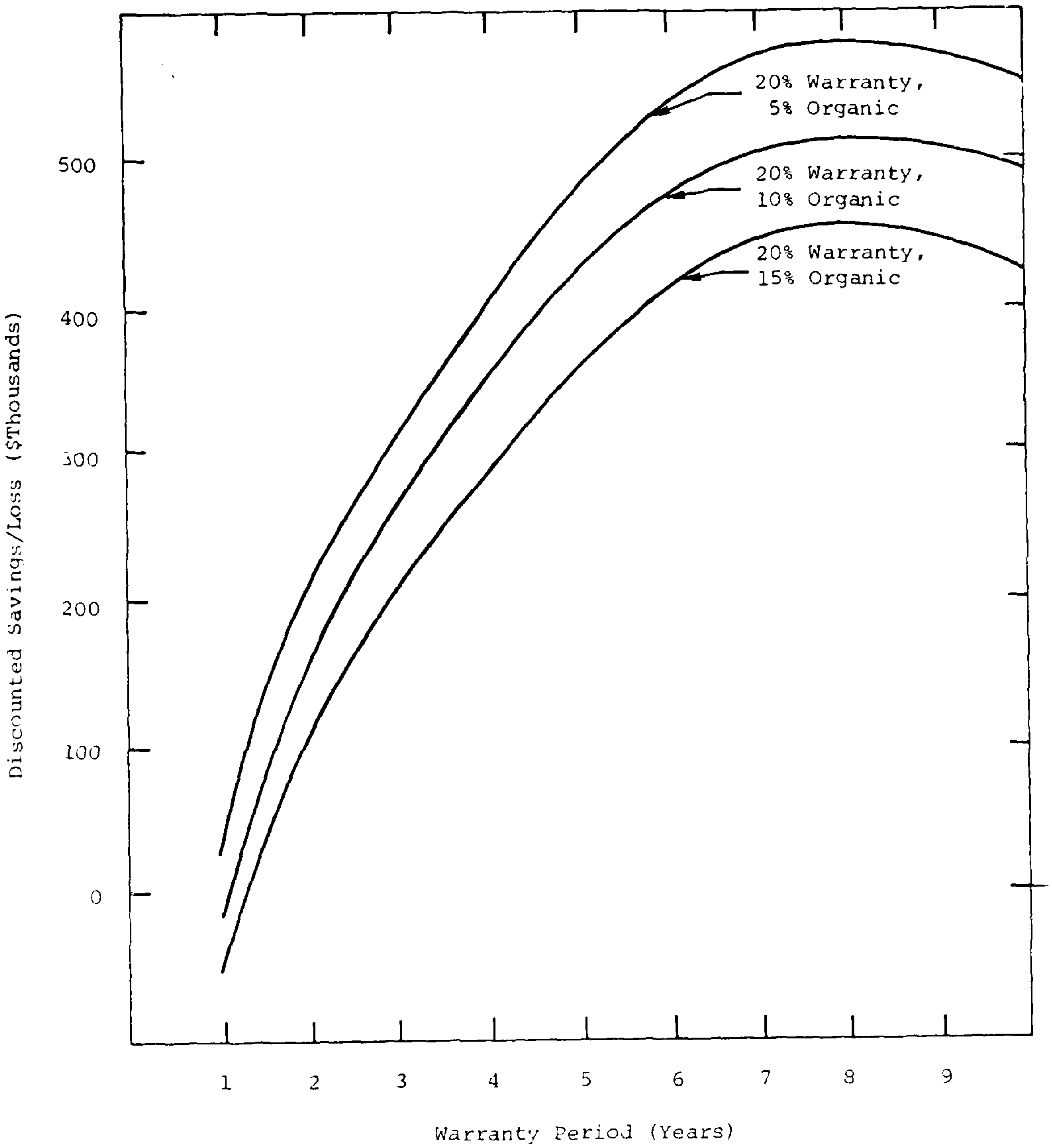

Figure 9-5. DISCOUNTED SAVINGS/LOSS BY WARRANTY PERIODS AS A FUNCTION OF MTBF GROWTH

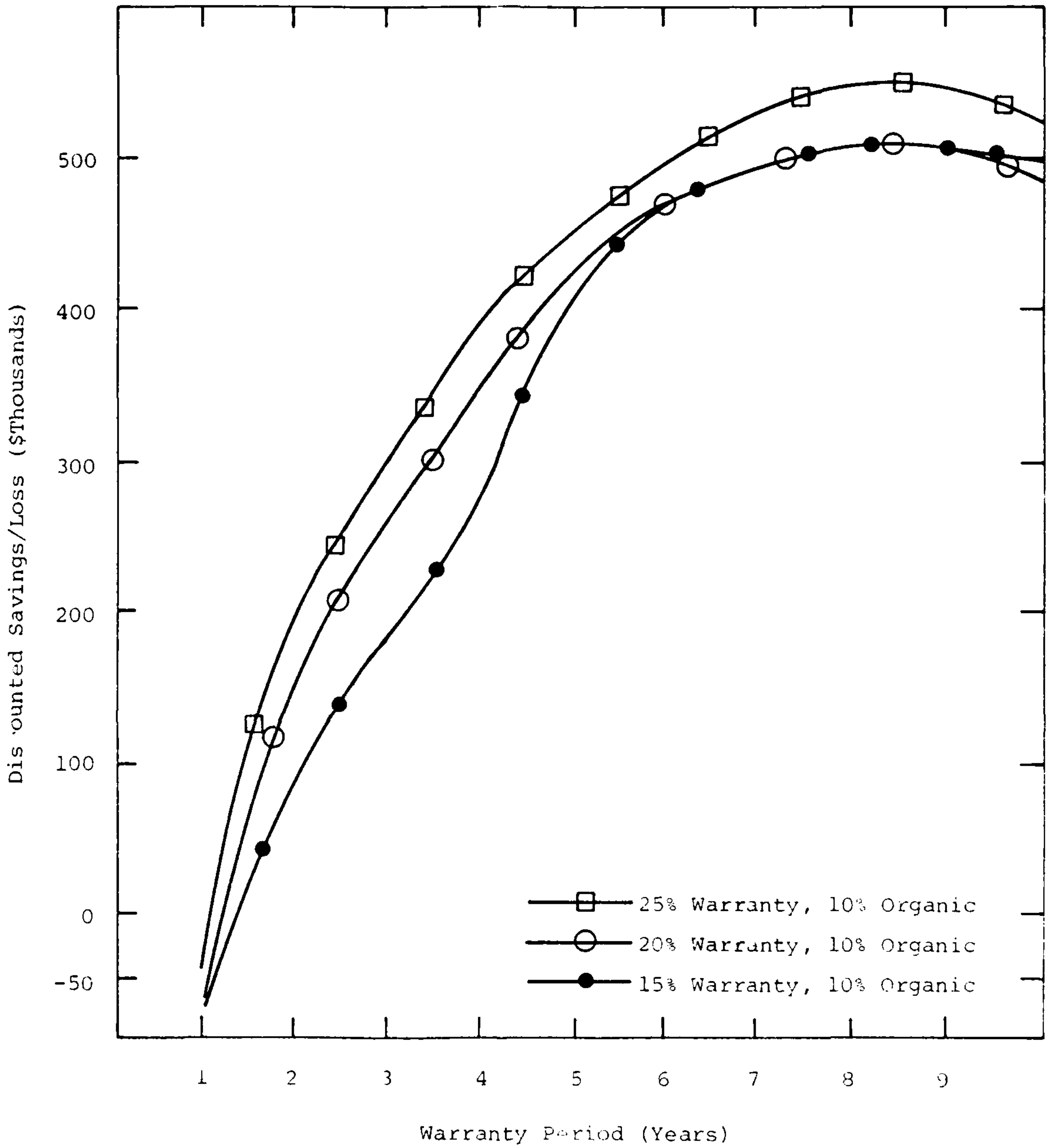

Figure 9-6. DISCOUNTED SAVINGS/LOSS BY WARRANTY PERIODS AS A FUNCTION OF WARRANTY MTBF GROWTH

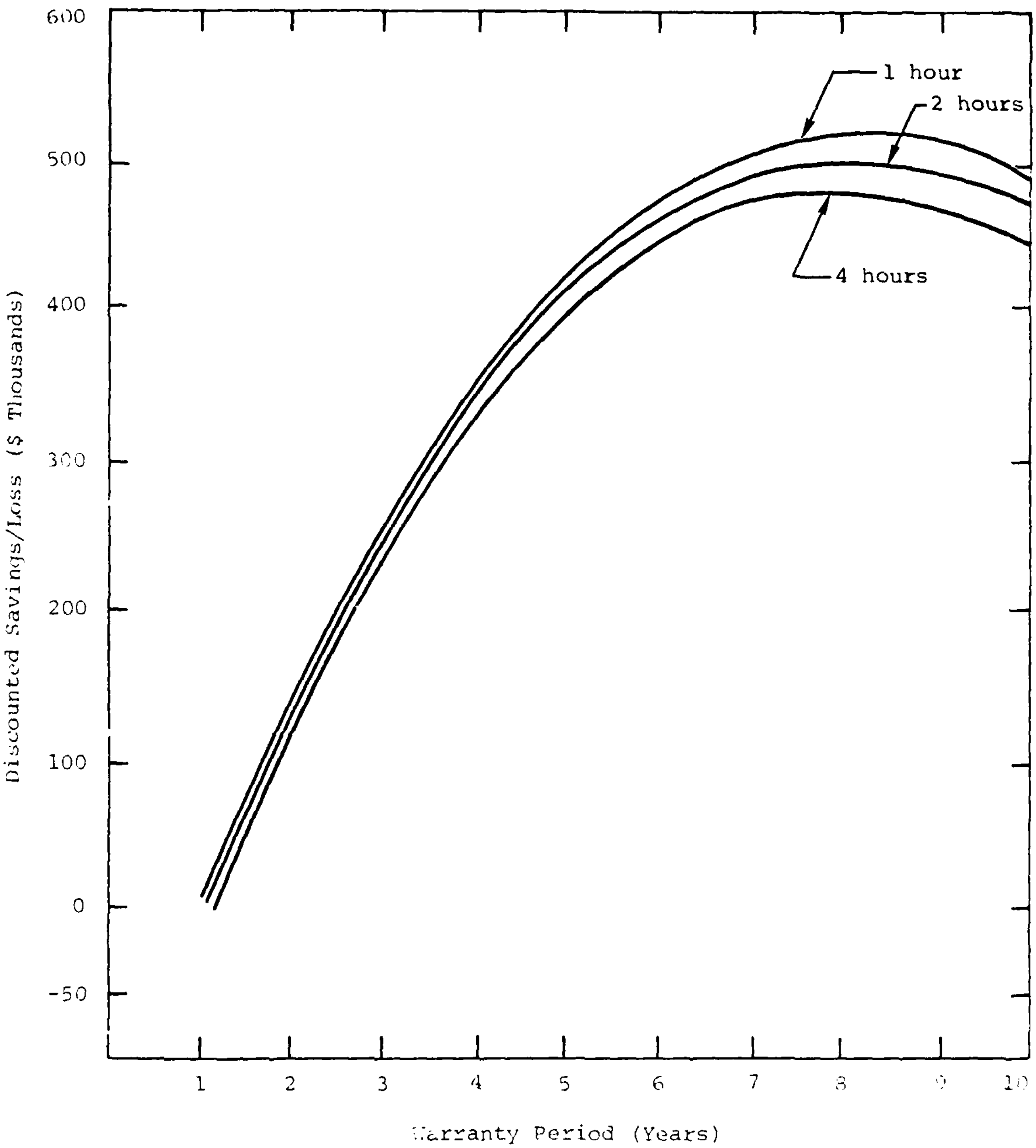

Figure 9-7. DISCOUNTED SAVINGS/LOSS BY WARRANTY PERIOD AS A FUNCTION OF AF ON-EQUIPMENT MAINTENANCE HOURS PER FAILURE

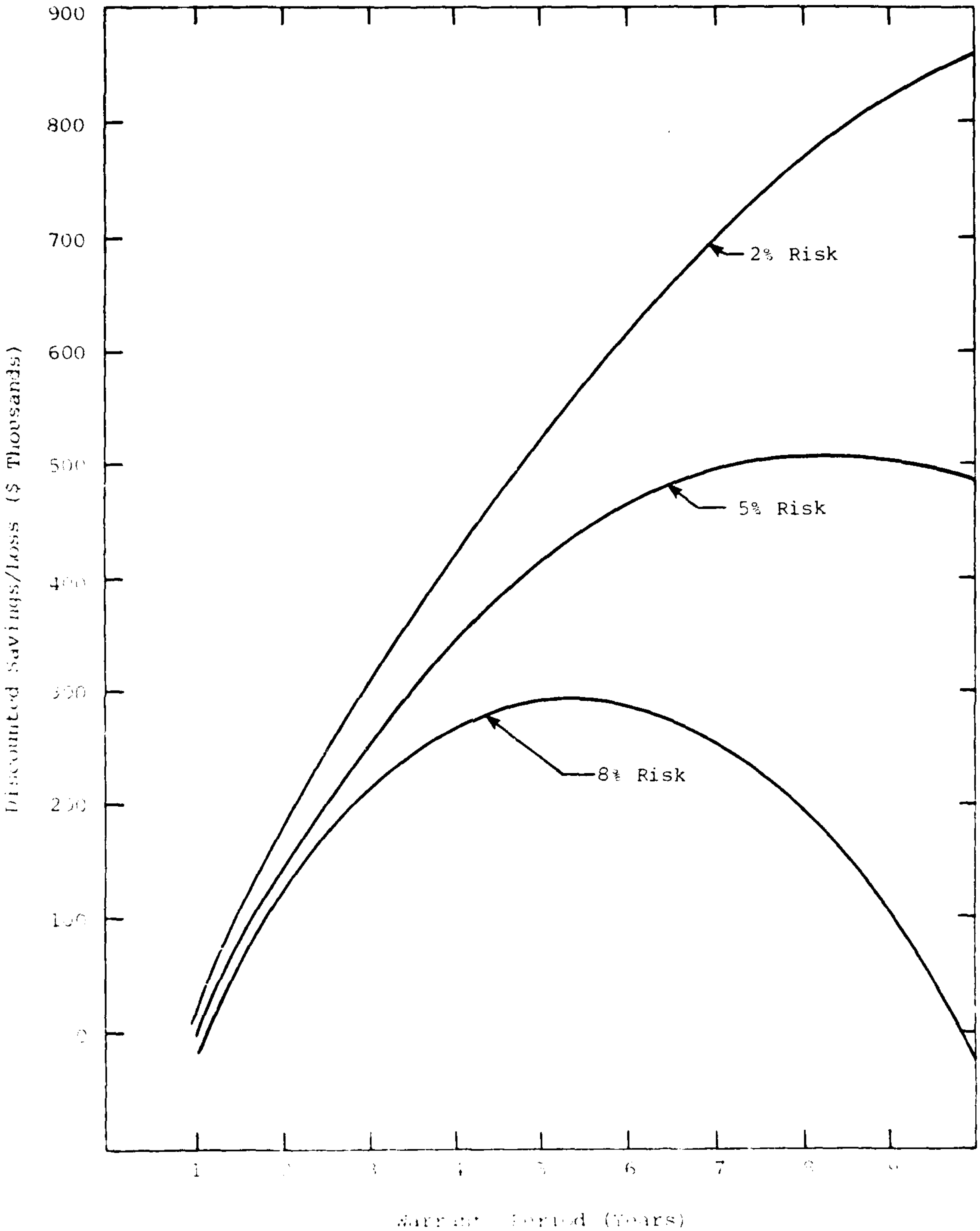

Figure 9-8. [illegible] BY WARRANTY PERIODS AS A [illegible]

runs, the 15 percent growth under warranty was insufficient to meet the MTBF guarantee value of 3,500 hours; therefore, consignment spares were required. Under the other warranty growth curves the guaranteed value was achieved.

To indicate how the model could be used for other sensitivity analyses, we varied the Air Force average corrective maintenance man-hours required at the on-equipment level for a failure involving a module under warranty. The results are shown in Figure 9-7. The four-hour curve in Figure 9-7 might be considered our base value; i.e., for the basic input, which includes four hours required for a failure involving a warranted module, the saving for a five-year module warranty is slightly less than $400,000. However, if through warranty improvements in troubleshooting and simplified procedures the contractor reduces the time the Air Force needs to accomplish this maintenance to one hour, the saving increases only to a little over $420,000. As noted for the various warranty periods, the saving is relatively insensitive to changes in this category of maintenance man-hours. For example, reducing the maintenance time from four hours to one hour, a 75 percent reduction, increases savings by about $20,000, but this represents less than 0.11 percent of the LCC. As shown later in this chapter, the saving or loss is relatively insensitive to some variables because a relatively small number of failures is expected. This is especially true for the maintenance parameter shown in Figure 9-7. A significant reduction in man-hours per individual failure becomes relatively insignificant over the life cycle because of the relatively small number of failures.

The final sensitivity analysis is shown in Figure 9-8, which indicates the sensitivity of warranty savings/loss as a function of risk used in the pricing algorithm. Since it may be several months before actual bid prices for the transponders are known, our sample analysis uses prices computed by the model. Because of the many assumptions made in our sample analysis, it is not expected that the price computed by the model will be comparable to the actual bid prices. Our purpose is to indicate the procedure that could be used, not to attempt to predict the price. Figure 9-8 shows how much the warranty savings/loss depends on the contractor risk factor used in the pricing equation. As the perceived risk increases, the warranty price increases and there is a resultant drop in the warranty savings. The longer the warranty period, the greater the impact of the risk. For example, for a five-year warranty savings are reduced approximately $240,000 when the risk is perceived and priced at 8 percent rather than 2 percent, where for a 10-year warranty the savings would be reduced by approximately $880,000, which actually results in a loss. Because of the importance of contractor risk, and its effect on warranty price, Section 9.4 demonstrates a procedure for quantifying these considerations.

9.4 WARRANTY PRICING CONSIDERATIONS

Using assumed data on the transponder procurement, this section shows how warranty pricing considerations can be analyzed. The effect on contractor

profits due to error in estimating MTBF will also be shown. The following data values are used in the sample analysis:

• Hardware - 140 Transponders @ $100,000 =	$14.000 million
• AGE	.500
• Miscellaneous	.200
• Total Cost Excluding Warranty	14.700
• Profit @ 12 percent	1.764
• Contract Value Excluding Warranty	$16.464

For the warranty, the following data values are assumed:

- Total Operating Hours for the Five-Year Warranty Period - 2,272,320*
- Contractor Cost per Failure - $300
- Contractor Cost per Good Return - $150
- "Retest OK" Rate = 10 percent
- Profit and Risk Factor = 15 percent
- Contractor Fixed Cost Associated with Warranty - $250,000
- Contractor Yearly Cost Associated with Warranty - $250,000 ($50,000/year)

The costs per failure and per good return may appear low when compared with those associated with many reparable items. However, it is expected that under the module-level warranty assumed here, a significant number of the returns will be printed circuit boards requiring only a component replacement. On the basis of these data, Table 9-5 summarizes contractor warranty cost, profit, and bid prices for four different MTBF levels. (We will subsequently use the 3,500-hour level as our base case for an MTBF guarantee.) As noted, we have included $250,000 for fixed costs and $250,000 for other yearly costs ($50,000 per year for five years for warranty administration and reporting).

For explanatory purposes, the computation is as follows below for the first case in Table 9-5:

- Total Failures Processed = $\frac{\text{Total Operating Hours}}{\text{MTBF}}$

$$= \frac{2,272,320}{2,500} = 909$$

---

*This value was calculated by using the installation and operating-hour schedule for the five-year warranty period shown in Appendix A. It is less than half the total ten-year operating time of 4,896,720 hours because some sets are not installed until the second and third years.

Table 9-5. ANALYSIS OF WARRANTY COSTS, PROFIT, AND BID PRICES FOR VARYING MTBF							
Average MTBF (Hours)	Total Returns Processed	Failures Processed	"Retest OK's" Processed	Incremental Warranty Costs ($ Millions)	Total Warranty Cost ($ Millions)*	Warranty Profit ($ Millions)	Warranty Price ($ Millions)
2500	1010	909	101	0.288	0.788	0.118	0.906
3000	841	757	84	0.240	0.740	0.111	0.851
3500	722	[illegible]	72	0.206	0.706	0.106	0.812
4000	631	568	63	0.180	0.680	0.102	0.782
*Total Warranty Cost = Incremental Cost + $0.25 million fixed costs + $0.25 million (total yearly cost: 5 years × $50,000 per year).							

- Total Returns = $\frac{\text{Total Failures}}{0.9} = \frac{909}{0.9} = 1010$
  ("Retest OK" rate is 10 percent; therefore, failures equal 90 percent of returns.)

- "Retest OKs" Processed = Total Returns - Total Failures
  = 1010 - 909 = 101

- Incremental Warranty Cost = (Failures Processed × $300/Failure Processed) + "Retest OKs" Processed × $150/"Retest OK" Processed
  Incremental Warranty Cost = (909 × $300) + (101 × $150)
  = $272,700 + $15,150 = $287,850
  = $0.288 million

- Total Warranty Cost = Incremental Warranty Cost + Fixed Cost + Total of Five Years Other Yearly Costs
  = $0.288 million + 0.250 million + 5 ($0.050 million)
  = $0.788 million

- Warranty Profit = Total Warranty Cost × (Profit + Risk Factor)
  = $0.788 million × (0.12 + 0.03) = $0.118 million

- Warranty Price = Total Warranty Cost + Warranty Profit
  = $0.788 million + $0.118 million = $0.906 million

Table 9-6 shows how contractor profits are affected by errors in estimating MTBF for warranty pricing. For explanatory purposes, the computation is shown below for the first case, in which the actual MTBF averages 2500 hours and the contractor's price is based on an average MTBF of 3000 hours.

The percent error in the MTBF bid value is

$$\left(\frac{\text{Bid} - \text{Actual}}{\text{Actual}} \times 100\right) = \frac{3000 - 2500}{2500} \times 100 = 20\%$$

Table 9-6. EFFECT ON CONTRACTOR PROFITS OF ERROR IN ESTIMATING MTBF*

Case	Actual MTBF	Bid MTBF	Percent Error	Bid Price ($ Millions)	Actual Cost ($ Millions)	Expected Profit ($ Millions) Based on Bid MTBF	Actual Profit ($ Millions) Based on Actual MTBF	Percent Increase (+)/ Decrease (-) from Base Prof.*
1	2500	3000	+20.0	17.315	15.488	1.875	1.827	-2.3
2	2500	3500	+40.0	17.276	15.488	1.870	1.788	-4.4
3	3000	2500	-16.7	17.370	15.440	1.882	1.930	+3.2
4	3000	3500	+16.7	17.276	15.440	1.870	1.836	-1.8
5	3500	2500	-28.6	17.370	15.406	1.882	1.964	+5.[illegible]
6	3500	3000	-14.3	17.315	15.406	1.875	1.909	+2.1
7	4000	2500	-37.5	17.370	15.380	1.882	1.[illegible]	+[illegible].4
8	4000	3000	-25.0	17.315	15.380	1.875	1.935	+3.[illegible]
9	4000	3500	-12.5	17.276	15.380	1.870	1.896	+1.4

*Base Profit is 1.870; i.e., the bid and actual MTBFs are both 3,500 hours. Profit = $1.764 million on contract exclusive of warranty + $0.106 million expected warranty profit for 3,500-hour MTBF (Table 9-[illegible]).

The bid price, including profit, is calculated as follows:

Price of Nonwarranty Items	$16.464 million
+ Price of Warranty (3,000 hours)	0.851
Total	$17.315 million

The actual cost is calculated as follows:

Cost of Nonwarranty Items	$14.700 million
+ Cost of Warranty (2,500 hours)	0.788
Total	$15.488 million

The expected profit is calculated as follows:

Profit for Nonwarranty Items (from first paragraph of Section 9.4)	$1.764 million
+ Expected Profit for Warranty (3,000 hours)	0.111
Total	$1.875 million

The actual profit is calculated as follows:

Bid Price	$17.315 million
Actual Cost	15.488
Profit	$ 1.827 million

The percentage increase or decrease in profit is calculated as follows:

$$\left(\frac{\text{Actual Profit - Base Profit}}{\text{Base Profit}}\right) \times 100 = \frac{\$1.827 \text{ million} - \$1.870 \text{ million}}{\$1.870 \text{ million}}$$

$$= -2.3\%$$

We note that there is little impact on profit as the contractor either overestimates or underestimates his bid MTBF price in relation to the actual MTBF obtained. This could have been anticipated because of the relationship between the profit on the hardware ($1.764 million) and the profit on the warranty ($0.102 to 0.118 million). For example, if the contractor overestimates the MTBF, his warranty costs will be higher and his warranty profit lower, but the warranty profit reduction is relatively insignificant when compared with the hardware profit. While the contractor would like to increase his profit by 6.4 percent (Case 7), this is probably unlikely. It is also unlikely that he will overestimate his MTBF by 40 percent (Case 2); however, even if he does, his profit is reduced by only 4.4 percent.

A very important factor that was excluded from the foregoing analysis is the MTBF guarantee commitment. If we assume an MTBF guarantee of 3,500 hours in Cases 5 through 9 in Table 9-6, the guarantee was met or exceeded, so that consignment spares were not applicable. However, in Cases 1 through 4, the MTBF guarantee of 3,500 hours may not have been met. The actual MTBF values were assumed to be averages over the warranty period. For Cases 3 and 4, if the average was 3,000 hours, it is likely that the MTBF in the final measurement period reached 3,500 hours and no consignment spares were required. In the first two cases, where the average was 2,500 hours, it is unlikely that 3,500 hours was attained. Therefore, we will examine the impact of consignment spares for Cases 1 and 2 (2,500-hour MTBF).

Section 5.4 of Appendix D provides a method for determining the number of consignment spares. The formula is:

$$m = (A \times S) - S_p$$

where

m = maximum number of MTBF pipeline consignment spare units (rounded to the next higher whole number)

S_p = number of spares currently consigned to the Government through the MTBF guarantee provisions

A = a number calculated as follows

$A = \frac{G}{M} - 1$ (if A is greater than 1, it shall be redefined as 1)

G = specified unit MTBF guarantee value for the measurement period

M = achieved MTBF of unit

S = "target" spares level calculated as follows:

$$S = \bar{N}\left(\frac{23 + T_r}{G}\right) AOT + 1.65 \sqrt{\bar{N}\left(\frac{23 + T_r}{G}\right) AOT}$$

where 23 represents the number of pipeline days to and from the contractor's facility and T_r is the required contractor repair turnaround time. AOT represents the average operating time of one installed unit per day.

For our sample application we will assume one measurement period at the end of the warranty period, with the final MTBF being 2,500 hours; i.e., the guaranteed MTBF was 3,500 hours but final achieved MTBF was 2,500 hours. Note that this situation is probably more unfavorable to the contractor than Case 1 or 2 would indicate. If the average MTBF over the period was 2,500 hours, the final MTBF was probably greater than 2,500 hours. However, to demonstrate the worst-case situation, we will use 2,500 hours as the final value and make the following computation:

$\bar{N}$ = average number of units installed = 140

Total Operating Hours = 2,272,320

$$AOT = \frac{2{,}272{,}320 \text{ hours}}{140 \times (365 \text{ days/year} \times 5 \text{ years})} = 8.89 \text{ hours per day}$$

$$A = \frac{3{,}500}{2{,}500} - 1 = 0.4$$

T_r = 22 days (assumed)

$$S = 140\left(\frac{23 + 22}{3{,}500}\right)(8.89) + 1.65 \sqrt{140\left(\frac{23 + 22}{3{,}500}\right) (8.89)}$$

$S = 22.6$

$m = (0.4 \times 22.6) = 9.04$ (rounded down to 9)

This computation would result in the contractor's being required to provide nine units to the Air Force at the end of the warranty period. A similar computation for a final MTBF of 3,000 hours requires four units to be provided. The resulting impact on profit due to these consignment spares is indicated in Table 9-7. The first three columns in the Table are extracted from Table 9-6. The fourth column is the contractor's cost for the quantity of spares (e.g., 9 units at $[illegible] each is $0.[illegible] million). The fifth column indicates the profit after reduction for the spares, and the last column indicates the corresponding percentage reduction in profit.

While consignment spares, if required, would reduce contractor profits significantly, they would still not result in a loss for the cases under analysis. Although not shown in the table, additional computations were made to determine the approximate break-even point. By using the consignment spares equation in the same manner as above, it can be shown that an MTBF of [illegible] hours at the end of the warranty period would require the contractor to provide [illegible] consignment spares. The contractor's cost to do

[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

so ($1.8 million) would approximately equal his profit on the hardware and result in an essentially break-even situation. It should be remembered that for this to occur, the contractor would have had to guarantee an MTBF of 3,500 hours and, after a five-year warranty period, to be unsuccessful in achieving a final MTBF above 2,000 hours. This is considered an extremely unlikely situation.

The last aspect of warranty pricing that we will consider here is the warranty price per year as a percentage of acquisition price. Such a percentage can be quite misleading since variations in equipment reliability, acquisition and repair costs, and operational usage rate can significantly affect the value. However, since this percentage is commonly used as a part of the evaluation of the cost of warranties on avionics equipment, we consider it here in relation to the transponder procurement.

In this section we assumed data values and computed the prices shown in Table 9-5. For example, for an average MTBF of 2,500 hours the computed warranty price was $0.906 million. Although the printout is not shown, we also used the price estimation equation in the model. To approximate 2,500 hours we input an initial MTBF of 1,875 hours which yielded an average of 2,638 hours and a resulting warranty price of $0.895 million. For comparison purposes we then computed bid prices on the basis of assumed prices per year as a percent of acquisition price. For example, for the delivery/installation schedule in Appendix A it can be shown that for a five-year warranty, the average warranty period for the entire population of equipment is 3.914 years. A 5 percent per year warranty price for the quantity of 140 transponders yields

3.914 years × 5%/year × $100,000/unit × 140 units = $2.74 million

We made a similar computation for 3 percent, and then entered these prices into the model as bid prices rather than have the model compute a price. The results, together with the two pricing methods mentioned above, are shown in Table [illegible]. As noted, a loss of $0.399 million occurs at 3 percent and it increases to $1.506 million at 5 percent. (The warranty savings/loss was not calculated for Table 9-5, but the warranty price is shown for comparison purposes.) The significance of this pricing analysis

Table 9-8. COMPARISON OF WARRANTY PRICING METHODS AND RESULTANT SAVING/(LOSS)			
Pricing Method	Percent per Year of Acquisition Price	Warranty Price ($ Thousands)	Warranty Saving/(Loss) ($ Thousands)
Model Price Algorithm	1.63	895	714
Assumed Repair Values, Table 9-5	1.65	906	Not Calculated
Percent per Year Computation	3	1,644	(399)
	5	2,740	(1,506)

is that for avionics equipment, a warranty price of 3 percent per year of the acquisition price would normally be considered "low". Yet in our ground-equipment example such a "low" price would result in a loss on the warranty. Because of the higher acquisition price per unit and higher reliability coupled with less total operating time (therefore, fewer failures), it is expected that for ground electronic equipment, warranty price expressed as a percent per year will be much lower than is commonly found in avionics procurements.

9.5 SUMMARY

This chapter has demonstrated an approach that can be used to evaluate the application of warranty-guarantee to ground electronic equipment. Procurement of ground TACAN transponders and data pertaining to them were assumed. The discussion in Section 9.2 indicated that the procurement meets the major criteria for a warranty with MTBF guarantee. Although there is more risk in applying an MTBF guarantee without warranty, depending on the competitive environment, the total dollar value of the hardware, and contractor risk perception, this may also be a viable option.

With the assumed data, the economic model described in Appendix A was used to evaluate the economic aspects of applying a warranty-guarantee. The base data resulted in a relatively small (2 percent) saving over full organic maintenance if a five-year warranty was applied and followed by five years of organic maintenance. Several inputs were varied to determine the sensitivity of the savings/loss to different input parameters. It was determined that for some variables the savings/loss was relatively insensitive to input changes because of the relatively small number of failures expected. Rather than anticipating a relatively large saving, the user may in this case consider a warranty-guarantee as insurance (through consignment spares) in the event the specified MTBF is not met. It then becomes a question of how much to pay in warranty-guarantee price for such insurance. Methods to address this question were previously discussed in Chapter Six (Subsection 6.4.4).

Section 9.4 examined pricing considerations, including the impact on profits if the contractor overestimates or underestimates the actual MTBF in relation to a guaranteed value. For the data values assumed it was shown that there was relatively little impact unless he grossly overestimated the MTBF and, after not being able to improve it to the guaranteed value, provided a relatively large quantity of consignment spares. Section 9.4 also addressed pricing of the warranty-guarantee and the impact on the warranty-guarantee savings/loss. It was shown for our example that unless the warranty-guarantee price was lower (as a percent-per-year of acquisition price) than typically bid for avionics equipment, the Government could incur a loss.

As indicated in the introduction to this chapter, the analysis was based primarily on assumed data, not on actual bid prices or Government organic-repair cost estimates. While no conclusions can be offered on the basis of our sample analysis, the techniques presented, coupled with use of the economic model developed, should aid in actual warranty-guarantee application decisions.

CHAPTER TEN

CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

The following principal conclusions were derived from the guidelines presented herein:

- As compared with avionics equipments, which represent the bulk of warranty experience to date, the ground electronic equipment area is diverse in terms of equipment types and operation and maintenance scenarios.
- Diversity in the ground electronic equipment area requires that special consideration be given to many factors that have an impact on warranty planning and evaluation.
- In some cases recent trends in the reliability of ground equipment may reduce the opportunity for reliability improvement; however, there may be opportunity to improve operational availability and to reduce maintenance and support costs.
- Several alternative warranty-guarantee plans are possible in the ground electronic equipment area; analysis is required to determine the most suitable, and the plans must be tailored to meet the special circumstances of individual procurements.
- Special circumstances (e.g., small quantities) that are often present in ground equipment procurements indicate that economic analysis is one of the most significant evaluation criteria. The economic model developed herein provides a key tool for this analysis.

10.2 RECOMMENDATIONS

This study has provided a range of possible warranty-guarantee plans which, depending upon the specific circumstances, can be effectively applied to ground electronic equipment. The following recommendations are provided regarding the use of these guidelines:

- Adequate procurement lead time must be scheduled to permit warranty-guarantee planning and analysis.

- Warranty-guarantee provisions should be tailored to specific procurements and to the objectives of the warranty-guarantee application.
- Since several of the plans developed herein are as yet untried in actual procurements, they should be exercised with care.
- The final decision to use any form of warranty-guarantee for ground electronic systems acquisition should be based on an economic analysis during evaluation of contractor proposals.

APPENDIX A

MATHEMATICAL MODEL AND COMPUTER PROGRAM FOR ORGANIC WARRANTY LCC ANALYSIS

1. INTRODUCTION

The objective of this appendix is to describe in detail the model and its associated computer program. Information is included concerning preparation of model input data as well as step-by-step operational instructions. A numerical example is provided to further illustrate the model's use. Detailed listings of the program code are included, together with a program flow chart. Equations used within the model are provided, as well as supporting parameter definitions.

This appendix documents the mathematical model and its associated computer program that is applicable to the economic analysis of life-cycle costs under warranty or organic maintenance. Chapter Six of this report described the model in general terms, provided guidelines on its potential applications, and described the life-cycle-cost elements employed in the economic analysis model.

2. MODEL CONCEPTS

2.1 Applicable Computers

The computer program is written in time-sharing FORTRAN Extended applicable to the Control Data Corporation Network Operating System (NOS). This study was performed by using the CYBERNET Services FTNTS subsystem. This program, with minor modifications, can be converted to other time-sharing or batch systems.

2.2 Model Overview

Figure A-1 presents an overview of the mathematical model's program logic. The model makes use of two basic data files:

- The general data file contains data describing the maintenance and warranty concepts, together with basic labor rates and similar information.
- The equipment file provides information concerning the item's reliability, acquisition cost, and other applicable descriptive data.

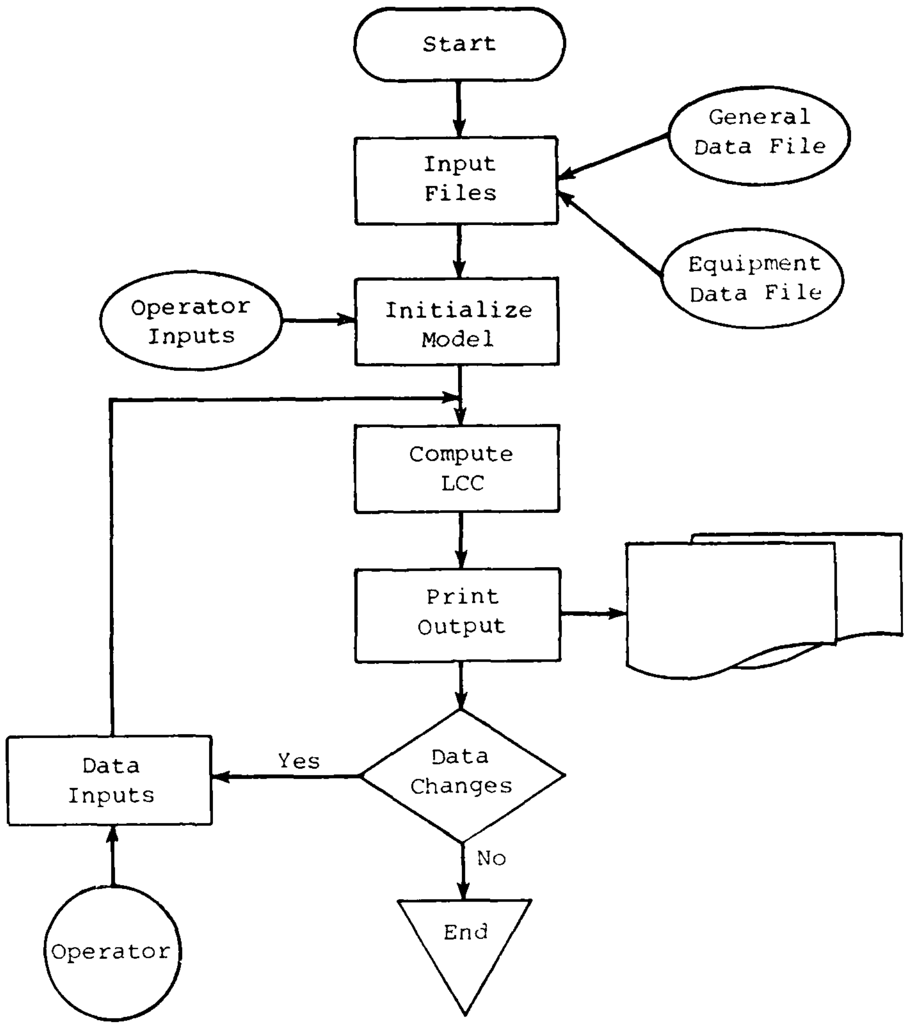

Figure A-1. MODEL OVERVIEW

Program initialization includes the instructions to the program concerning the types and amount of printout desired. In addition, instructions are provided concerning the various warranty periods the analyst wishes the program to exercise.

With all inputs entered, the program computes the unit's MTBF on the basis of growth criteria furnished for selected periods of interest. Spare requirements are computed together with corrective and preventive maintenance costs. With these factors accountable, total life-cycle cost is computed for organic maintenance for various time periods as specified by the input parameters. Results of the analysis are provided to the analyst as specified by the initialization.

Changes may be made to the data set to perform a sensitivity analysis. These changes will modify portions of the two basic input data files, thus allowing sequential analysis runs.

2.3 Maintenance Concept Representation

A large portion of the model is to compute the maintenance cost for various organic and warranty maintenance concepts. To gain insight for proper model use and input data development, the approach used within the model to develop maintenance costs will be described.

The maintenance concept involves corrective maintenance, preventive maintenance, and sparing. Subsection 2.3.1 presents the algorithms for both corrective and preventive maintenance and the interrelationship between corrective maintenance and sparing.

2.3.1 Corrective Maintenance

The equation for the average corrective maintenance cost ($ACMC_k$) per year k is

$$ACMC_k = 12 \left\{ \sum_{i=1}^{2} \sum_{\ell=1}^{B} \left[(ALRCM_i) X_{i\ell k} \right] + Y_k (ALRCM_3) \right\}$$

where

$ALRCM_i$ = average labor rate at each maintenance level i (weighted for both subassemblies and modules)

i = index on maintenance levels (1 - organizational, 2 - intermediate, 3 - depot)

ℓ = index of base types

B = number of base types

$X_{i\ell k}$ = corrective maintenance man-hours per maintenance level per base type per month for year k (two maintenance levels, organizational and intermediate)

Y_k = corrective maintenance man-hours for the depot per month for year k

The algorithm is designed to llow for fixed man-hours or a demand-driven man-hours calculation. The computer program selects the greater of the two as follows:

$$X_{i\ell k} = \mathrm{MAX}[DX_{i\ell k}, FX_{i\ell}]$$

$$Y_k = \mathrm{MAX}[DY_k, FY]$$

where

$DX_{i\ell k}$ = demand-driven corrective maintenance man-hours for organizational and intermediate levels per base type per month per year k

$FX_{i\ell}$ = fixed corrective maintenance man-hours for organizational and intermediate levels per base type per month

DY_k = demand-driven corrective maintenance man-hours at the depot per month for year k

FY = fixed corrective maintenance man-hours at the depot per month

The demand-driven $DX_{i\ell k}$ is

$$DX_{i\ell k} = ACMHM_{i\ell k}\ CNSI_{\ell k}$$

where

$CNSI_{\ell k}$ = the number of installations at base type ℓ in the year k

$ACMHM_{i\ell k}$ = corrective maintenance man-hours per maintenance level per base type per month per installation for year k

$$ACMHM_{i\ell k} = \frac{HM(l)}{SMTBD\ (k)}\ [D_i\ (CMS_i) + F_i\ (CMM_i)]\ \text{for } i = 1, 2$$

where

HM(l) = average operating hours per month for base type l

SMTBD(k) = mean time between demands of the system in year (k)

D_i = proportion of total subassembly-level maintenance tasks processed at the i^{th}, maintenance level

F_i = proportion of total module-level maintenance tasks processed at the i^{th}, maintenance level

CMS_i = average man-hours for a subassembly task at the i^{th} maintenance level

CMM_i = average man-hours for a module task at the i^{th} maintenance level

Similarly, the demand-driven depot corrective maintenance, DY_k, is

$$DY_k = \left(\frac{\sum_{i=1}^{B} HM(1)CNSI_{IK}}{SMTBD(k)} \right) [D_3(CMS_3) + F_3(CMM_3)]$$

The average corrective maintenance labor rate $ALRCM_i$ can be found from the following (Note: this computation is not included in the computer program):

$$ALRCM_i = \sum_{r=1}^{n} V_{ir} R_r (1 + Q_i) (1 + P_i)$$

2.3.2 Probabilities of Maintenance Actions

An important set of parameters for computing corrective maintenance times are the corrective maintenance weighting factors D_i and F_i. These weights are computed within the program on the basis of a series of probabilities used to describe the maintenance activity at the various levels.

To determine these probabilities, a node chart pipeline flow is necessary. This flow chart is illustrated in Figure A-2, which contains the input probabilities for full organic support. The flow chart is constructed from left to right starting with system demands at node 1. The system demands are divided into two paths. The solid lines represent the flow of subassemblies, and the dashed lines represent the flow of modules.

The node chart is constructed so that all probabilities associated with the flow out of each node must sum to one. For instance, at node 2, POSO and 1 - POSO sum to one. The dashed line that flows from node 1 to node 2 to node 3 and then to node 6 indicates the flow of a module which, due to a repair of a subassembly at the intermediate level, caused an action to be taken on a module. An assumption has been made that for each subassembly repaired at the intermediate level, a failed module will be generated.

Consider the flow of subassemblies. The probability PSO states that at node 1 action will be required on a subassembly. Proceeding to node 2, POSO is the probability that a subassembly will be repaired at the organizational level. The remaining subassemblies continue to node 3, the intermediate level of maintenance. The following three actions can be taken of a subassembly at the intermediate level:

- The subassemblies can Retest OK (RTOK). This situation is accounted for by the term RTOKS, which is the probability of Retest OK of a subassembly at the intermediate level.
- A subassembly will be determined Not-Repairable-This-Station (NRTS) and is sent to the depot, node 4 . This situation is accounted for by PNRTSSO, the probability that a subassembly is not repairable at the intermediate level of maintenance.

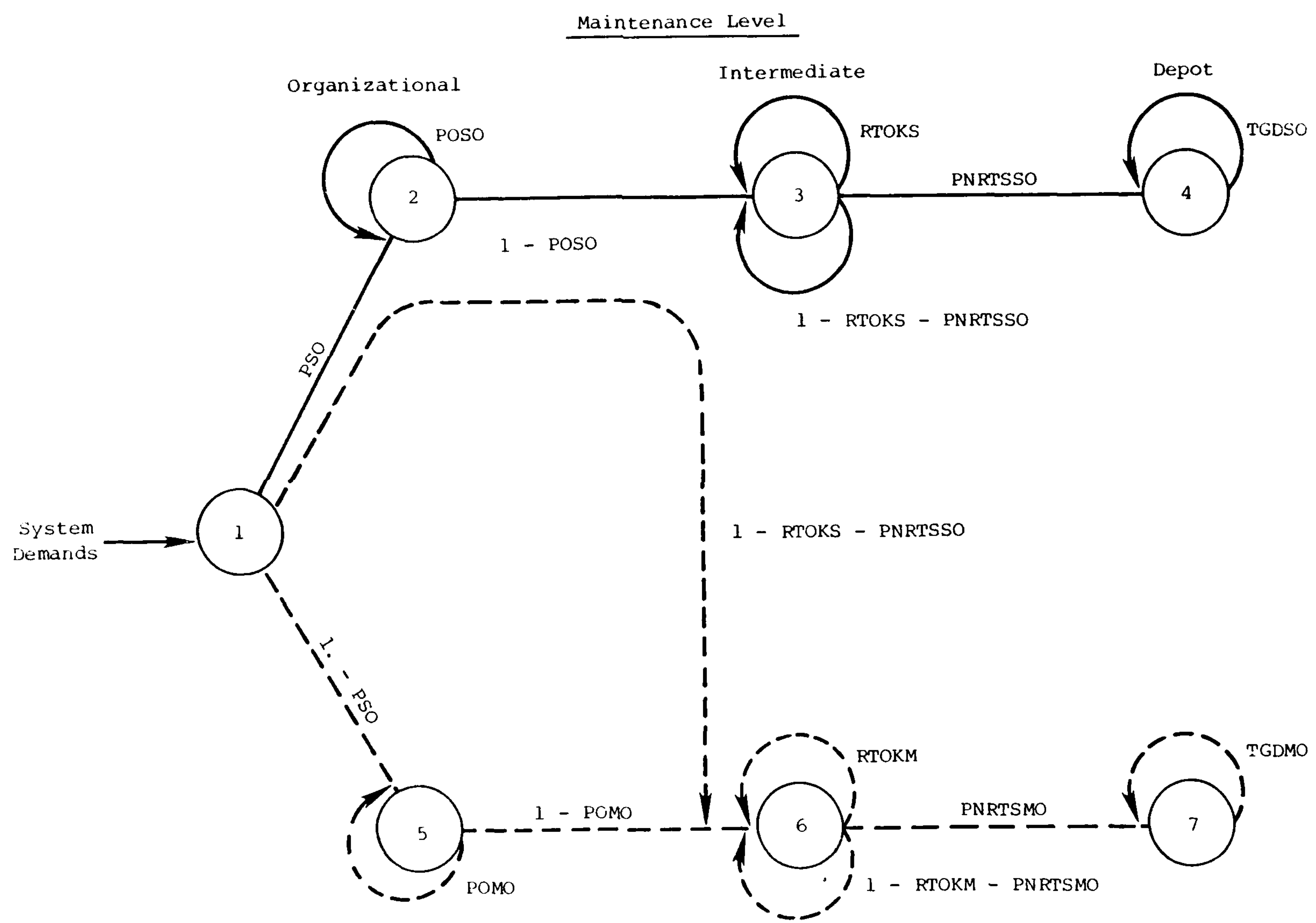

Figure A-2. FLOW CHART OF THE MAINTENANCE CONCEPT NODES

- Repair the subassembly at the intermediate level. It has been assumed that to repair a subassembly requires a module spare. Thus for every subassembly repaired at the intermediate level, a module demand is generated for the intermediate level.

At node 4 , the depot, two actions can be taken -- the subassembly can test "good" (which is accounted for by the probability TGDSO), or the subassembly will require repair at the depot.

The second path from node 1 is the percentage of modules that require action due to system demands at node 1. This probability is 1 - PSO. The percentage of modules that can be repaired at the organizational level, node 5, is accounted for by POMO (the probability that a module will be repaired at the organizational level). The remaining modules, accounted for by 1 - POMO, are sent to the intermediate level, node 6. The following three actions can be taken on a module at the intermediate level:

- The module can Retest OK. This situation is accounted for by RTOKM, the probability of a module Retesting OK at the intermediate level.
- The module cannot be repaired at the intermediate level and is sent to the depot, node 7. This action is accounted for by PNRTSMO, the probability that a module cannot be repaired at the intermediate level and is sent to the depot.
- Repair the modules at the intermediate level. This probability is 1 - RTOKM - PNRTSMO.

At node 7 , the depot, two actions can be taken on the modules -- the module can test "good" (which is accounted for by the probability TGDMO), or the module will require repair at the depot.

The nine probabilities in Figure A-2 will thus specify the flow of subassemblies and modules. These probabilities can be specified independently of one another except in the case of the intermediate nodes, where three actions can occur. For node 3 and node 6 , the Retest OK and the probability of NRTS must be less than or equal to one.

The nine probabilities that have described the maintenance flow are inputs required for the economic model. Specifically, they are the inputs for organic maintenance. A similar set of probabilities is required for warranty. The following is a one-for-one comparison of the organic and warranty probability inputs:

Organic	Warranty
PSO	PSW
POSO	POSW
PNRTSSO	PNRTSSW
POMO	POMW
PNRTSMO	PNRTSMW
TGDSO	TDGSW
TGDMO	TDGMW

It should be noted that RTOKS and RTOKM are not included in the above list because it has been assumed that the Retest OK probabilities at the intermediate level are not a function of whether organic or warranty support exist. It should also be noted that the seven input probabilities for warranty will change depending on the level of warranty. For example, if the warranty includes contractor maintenance at the depot and intermediate level, the probability that an item will be NRTS'd to the depot will probably be different than if the contractor warranty is at the depot only, and the Air Force is responsible for intermediate maintenance. This factor must be considered when constructing the probability inputs.

Thus far it has been assumed that three levels of maintenance exist -- organizational, intermediate, and depot. There are situations in which no distinct intermediate levels of maintenance exist, although there is a base spares supply; i.e., failures are NRTS'd direct to the depot from organizataional maintenance. The model can account for this situation if the following parameters are inputted:

- RTOKS = 0.0
- RTOKM = 0.0
- PNRTSSO = 1.0
- PNRTSMO = 1.0
- PNRTSSW = 1.0
- PNRTSMW = 1.0

These parameter values tell the model to spare at the intermediate level but not to repair at the intermediate level.

The probabilities discussed are related to system demands and not system failures. The relationship of system demands to system failures is

$$\gamma_D = \frac{\gamma_F}{1 - FPR}$$

where

γ_D = system demands

γ_F = system failures

FPR = false pull rate

From the previous discussion, it can be seen that a false pull rate is required for each type of support (organic or warranty). False pull rates are determined [illegible] false pulls at the intermediate and depot level. [illegible] false pull rates, the failure demands and fals

pulls must be identified. After some algebraic manipulation, it can be shown that the false pull rates for organic and warranty are as follows:

- Organic false pull rates (FPRO)

$$\begin{aligned} FPRO = {} & PSO \times (1 - POSO) \times (RTOKS + PNRTSSO \times TGOSO) \\ & + [(1 - PSO) \times (1 - POMO) + PSO \times (1 - POSO) \\ & \times (1 - RTOKS - PNRTSSO)] \times (RTOKM + PNRTSMO \times TGDMO) \end{aligned}$$

- Warranty false pull rates (FPRW)

$$\begin{aligned} FPRW = {} & PSW \times (1 - POSW) \times (RTOKS + PNRTSSW \times TGDSW) \\ & + [(1 - PSW) \times (1 - POMW) + PSW \times (1 - POSW) \\ & \times (1 - RTOKS - PNRTSSW)] \times (RTOKM + PNRTSMW \times TGDMW) \end{aligned}$$

These false pull rates are calculated internal to the economic computer model. In addition to these calculations, the program also calculates the corrective maintenance weighting factors D_i and F_i. These factors can be written directly from the node chart of Figure A-2. The corrective maintenance weighting factors for organic and warranty support are as follows:

- Organic corrective maintenance weighting factors

$$\begin{aligned} D_1 &= PSO \\ D_2 &= PSO \times (1 - POSO) \\ D_3 &= D_2 \times PNRTSSO \\ F_1 &= 1 - PSO \\ F_2 &= F_1 \times (1 - POMO) + PSO \times (1 - POSO) \times (1 - RTOKS - PNRTSSO) \\ F_3 &= F_2 \times PNRTSMO \end{aligned}$$

- Warranty corrective maintenance weighting factors

$$\begin{aligned} D_1 &= PSW \\ D_2 &= PSW \times (1 - POSW) \\ D_3 &= D_2 \times PNRTSSW \\ F_1 &= 1 - PSW \\ F_2 &= F_1 \times (1 - POMW + PSW \times (1 - POSW) \times (1 - RTOKS - PNRTSSW) \\ F_3 &= F_2 \times PNRTSMW \end{aligned}$$

where

R_r = rate for r^{th} labor class

V_{ir} = proportion of r^{th} labor class used at i^{th} maintenance level

n = number of labor classes

Q_i = adjustment factor to account for cost of materials at i^{th} maintenance level

P_i = adjustment factor to account for cost of travel at i^{th} maintenance level

2.3.3 Preventive Maintenance

The equation for the average preventive maintenance cost ($APMC_k$) per year k is

$$APMC_k = 12 \left\{ \left[\sum_{i=1}^{2} \sum_{\ell=1}^{B} (ALRPM_i) Z_{i\ell k} \right] + (ALRPM_3)(ZD_k) \right\}$$

where

$ALRPM_i$ = average labor rate for preventive maintenance at the i^{th} level of maintenance

i = index for maintenance level (1 - organizational, 2 - intermediate, 3 - depot)

ℓ = index for base types

B = number of base types

$Z_{i\ell k}$ = average preventive maintenance man-hours per base per month for year k for the organizational and intermediate levels

ZD_k = average preventive maintenance man-hours per month per year k at the depot

The algorithm is designed to allow for fixed man-hours or a demand-driven man-hours calculation. The computer program selects the greater of the two as follows:

$$Z_{i\ell k} = MAX[DZ_{i\ell k}, FZ_{i\ell k}]$$
$$ZD_k = MAX[DZD_k, FZD]$$

where

$DZ_{i\ell k}$ = demand-driven preventive maintenance man-hours for organizational and intermediate levels per base type per month per year k

$FZ_{i\ell k}$ = fixed preventive maintenance man-hours for organizational and intermediate levels per base type per month

DZD_k = demand-driven preventive maintenance man-hours at the depot per month

FZD = fixed preventive maintenance man-hours at the depot per month

The demand-driven $DZ_{i\ell k}$ is

$$DZ_{i\ell k} = H_{\ell}(PMR_i)\ (CNSI_{\ell k})$$

where

H_{ℓ} = average operating hours per month for base type ℓ

$CNSI_{\ell k}$ = number of installations at base type l for the year K

PMR_i = preventive maintenance service for the i^{th} level of maintenance per installation

PMR_i is calculated off line as follows

$$PMR_i = \sum_{j=1}^{m} P_{ij}/F_{ij}$$

where

F_{ij} = operating hours between the j^{th} preventive maintenance task at the i^{th} level of maintenance per installation

P_{ij} = time in man-hours required to perform the j^{th} preventive maintenance task at the i^{th} level of maintenance

Consider the following example to determine PMR_1: Two types of preventive maintenance will be performed on each system. The first preventive maintenance is once a week and requires one hour. The second preventive maintenance is once a month and requires three hours. Both are for the organizational level. The system operates 24 hours a day, 30 days a month. Thus PMR_1 is

$$PMR_1 = \frac{1.0}{24(7)} + \frac{3.0}{24(30)}$$

$$= (0.00595 + 0.004166)$$

$$= 0.01012$$

This method allows for the summing of many different types of preventive maintenance at each level of maintenance.

The demand-driven depot preventive maintenance DZD_k is as follows

$$DZD_k = (PMR_3) \sum_{\ell=1}^{B} H_{\ell}\ (CNSI_{\ell k})$$

The average labor rate for preventive maintenance, $ALRPM_i$, can be found from the following:

$$ALRPM_i = \sum_{r=1}^{n} W_{ir}\ R_r\ (1 + M_i)\ (1 + T_i)$$

where

R_r = rate for labor class r

W_{ir} = proportion of r^{th} labor class used at i^{th} maintenance level

n = number of labor classes

M_i = adjustment factor to account for cost of material used as part of preventive maintenance

T_i = adjustment factor to account for cost of travel incurred in accomplishing preventive maintenance

3. DATA PREPARATION

The computer program for the mathematical model has two forms of inputs: (1) two data files constructed prior to program execution and (2) interactive inputs entered through an interactive terminal. This section presents the former, while the interactive inputs are discussed in Section 4.

The general data file contains non-varying data for subassembly or module type. It includes, for example, labor rates, contractor profit percentages, and training costs. The second file contains equipment-level data, describing the subassembly and modules included within the equipment.

A line of data for either file has the following form:

Line Number   Blank   1st Data Element, 2nd Data Element, etc.

A sample data line for inputting labor rates of $10.11, $11.50, and $14.00 would be

55   10.11, 11.50, 14.00

where 55 is the line number, and the subsequent numbers are the labor rate data. The line number is a convenience for the user and is ignored by the program, but it cannot be omitted. This data format for the general and equipment files must be structured as outlined in the following subsections.

3.1 General Data File

This file describes, by using input parameters, the maintenance concepts for both organic and warranty alternatives. In addition, the various rate and other cost functions are to be supplied. The format (order) of the general data file is presented in Table A-1. Program line numbers 610 through 890 and line numbers 1170, 1400, 1760, and 2010 are statements that read this file. Definitions of the input terms contained within Table A-1 are presented in Table A-2.

Table A-1. CONTENTS OF GENERAL FILE FOR L[illegible] DATA

Symbol	Input Data Elements
L1*	PNRTSSO, PNRTSSW, PNRTSMO, PNRTSMW
L1	PSO, PSW, FPR
L1	POSO, POSW, POMO, POMW
L1	TGDSO, TGDSW, TGDMO, TGDMW
L1	TBRCO, TRBCW, TOSS, TOSM
L1	TDRCSO, TRDCSW, TDRCMO, TDRCMW
L1	BMORT, VMOD, PUDAF
L1	PSUFF, BY, DR, NWC
L1	CFCMHD, AFCMHD
L1	CALRCM(1), CALRCM(2), CALRCM(3)
L1	AALRCM(1), AALRCM(2), AALRCM(3)
L1	CCMML(1), CCMML(2), CCMML(3)
L1	ACMMLO(1), ACMMLO(2), ACMMLO(3)
L1	ACMMLW(1), ACMMLW(2)
L1	CCMMM(1), CCMMM(2), CCMMM(3)
L1	ACMMO(1), ACMMO(2), ACMMO(3)
L1	ACMMW(1), ACMMW(2)
L1	CFPMMD, AFPMMD
L1	CALRPM(1), CALRPM(2), CALRPM(3)
L1	AALRPM(1), AALRPM(2), AALRPM(3)
L1	PMRO(1), PRMO(2), PRMO(3)
L1	PMRW(1), PRMW(2), PMRW(3)
L1	A[illegible]BO, A[illegible]BW, AGDO, FA[illegible], FAGD
L1	[illegible]PW, WTBO, WTDO, WTBW, RTP
L1	DTAO, DTAW
L1	P[illegible]F, [illegible]T, DWF, DTP, RIWFF, Y[illegible]THW
L1	NPC[illegible], NPCW, [illegible]IM
L1	OTHO, OTHW, [illegible]THWO, YOTHO, Y[illegible]THW, [illegible]TRANS
L1	[illegible]FET, [illegible]
L1	PCT[illegible], P[illegible]T[illegible], [illegible]LIM, NPX
LS**	***NB(K), HM(K), NBY(K), NSCH(1,K)
LS	†NSCH(2,K), NSCH(3,K), NSCH(4,K), NSCH(5,K), NSCH(6,K)
LS	††NSCH(7,K), NSCH(8,K), NSCH(9,K), NSCH(10,K), NSCH(11,K)
LC#	CF[illegible]MHB(1,K), CF[illegible]MHB(2,K), AF[illegible]MHB(1,K), AF[illegible]MHB(2,K)
LF##	[illegible]MB(1,K), [illegible]MB(2,K), A[illegible]MB(1,K), A[illegible]MB(2,K)

*The symbol L1 is used to denote a line number in the file.
**Repeat lines LS for each base type.
***Inputs for K type base.
†Five consecutive years of inputs for K type base.
††Five more consecutive years of input for K type base, if any.
#Repeat line LC for each base type.
##Repeat line LF for each base type.

Table A-2. DEFINITION OF INPUT TERMS

PNRTSSO. The probability at the intermediate level that a subassembly is sent back to the depot for repair under organic maintenance because of Not-Repairable-This-Station determination. Generally, subassemblies are repaired at the intermediate level of maintenance by module replacement; therefore, this parameter value is normally low (i.e., under 0.10).

PNRTSSW. The probability at the intermediate level that a subassembly is sent back to the contractor for repair because of Not-Repairable-This-Station determination when a warranty exists. This parameter value will vary depending on the type of warranty selected.

PNRTSMO. The probability at the intermediate level that a module is sent back to the depot for repair under organic maintenance because of Not-Repairable-This-Station determination. Generally, this parameter is low if component parts are stocked at the base, but it can be high if components are not stocked at the base.

PNRTSMW. The probability at the intermediate level that a module is sent to the contractor for repair because of a Not-Repairable-This-Station determination when a warranty exists. This parameter can be high if full module warranty is selected, or it can be as low as that experienced under organic maintenance.

PSO. The probability that a system demand at the organizational level will require action to be taken on a subassembly under organic maintenance. Generally, this parameter will be high, usually in the range of 0.90.

PSW. The probability that a system demand at the organizational level will require action to be taken on a subassembly on which a warranty exists. Generally, this parameter is equal to or greater than PSO.

RTOKS. The probability that a subassembly demand at the intermediate level will result in a Retest OK. This applies to both organic and warranty.

RTOKM. The probability that a module demand at the intermediate level will result in a Retest OK. This applies to both organic and warranty.

POSO. The probability that a subassembly is repaired at the organizational level under organic maintenance. This parameter is usually low, i.e., 0.05 or less unless the equipment is remote or large, thus making transportation of the item impractical.

POSW. The probability that a subassembly is repaired at the organizational level when a warranty exists. This parameter is usually lower than POSO, but it may become larger if the equipment is remote or difficult to transport.

POMO. The probability that a module is repaired at the organizational level under organic maintenance. This parameter is usually low, i.e., 0.05 or less, unless some unusual circumstance dictates a high degree of module repairs on line.

(continued)

Table A-2. (continued)

POMW. The probability that a module is repaired at the organizational level when a warranty exists. This parameter is usually equal to or lower than POMO.

TGDSO. The probability that a subassembly sent to the depot will test "good" under organic maintenance.

TGDSW. The probability that a subassembly sent to the depot will test "good" when a warranty exists. (Note: This parameter is affected by the choice of the type of warranty.)

TGDMO. The probability that a module sent to the depot will test "good" under organic maintenance.

TGDMW. The probability that a module sent to the depot will test "good" when a warranty exists. (Note: This parameter is affected by the choice of the type of warranty.)

TBRCO. The base-repair-cycle time in days for organic maintenance, which is an average time. It applies to the following scenarios:

- The time from when an item is removed from the system, taken to the intermediate level, checked, repaired, and placed in the intermediate spares pool.
- The time from when an item is removed from the system, taken to the intermediate level, retested OK, and placed in the intermediate spares pool.
- The time from when an item is removed from the system, taken to the intermediate level, checked, and determined that is was not repairable at the intermediate level of maintenance.

The assumption has been made that, on the average, each of these scenarios will have the same base-cycle time. It has also been assumed that subassemblies and modules have the same base-cycle time.

TBRCW. The base-repair-cycle time in days for warranty maintenance; similiar to TBRCO.

TOSS. Order and ship time for a subassembly in days. This period starts when an item is ordered and ends when the item is received at the intermediate level.

TOSM. Order and ship time for a module in days. This period starts when an item is ordered and ends when the item is received at the intermediate level.

TDRCSO. The depot-repair-cycle time in days under organic maintenance for a subassembly. This period applies to items that must be sent to the depot for repair. The period starts when the subassembly enters base check-out and includes the base-repair-cycle time, transportation to depot, repair at depot, and placement into stock.

(continued)

Table A-2. (continued)

TDRCSW. The depot-repair-cycle time for a subassembly in days when a warranty exists. The period is the same as for TDRCSO.

TDRCMO. The depot-repair-cycle time for a module in days under organic maintenance. This period is the same as for TDRCSO.

TDRCMW. The depot-repair-cycle time for a module in days when a warranty exists. This period is the same as for TDRCSO.

BMORT. The depreciation factor for determining the value of excess subassemblies at time of transition from warranty to organic maintenance. The equation for this value is CL × (1 - TW/NY) × BMORT, where CL is the subassembly cost, TW is the warranty period, and NY is the number of life-cycle years being considered. If BMORT is equal to 1.0, linear depreciation results. For example, if the warranty period is four years and the life-cycle period is 10 years, each excess subassembly is valued at CL × (1 - 4/10) = 0.6 CL. A value of BMORT less than 1 implies that a subassembly depreciates faster than linear depreciation, while a value of BMORT greater than 1 implies slower-than-linear depreciation.

VMOD. The depreciation factor for determining the value of excess modules at the time of transition from warranty to organic maintenance. This parameter is BMORT's analogous counterparts for modules.

PUDAF. The fraction of required discard-at-failure modules available at transition that will be used for future organic maintenance. After disassembly of excess subassemblies, a number of discard-at-failure modules may be available that could be used for meeting future replacement requirements. However, not all of these modules may see service because of losses occurring in disassembly, shipping, handling, and inventory control.

PSUFF. Spares sufficiency probability. The steady-state probability that a spare will be available when required.

NY. The number of life-cycle years under consideration. Generally, NY represents the expected useful life of the equipment but may be any selected time period.

DR. The annual discount rate. Use of a discount rate (typically 0.10) translates all future dollar expenditures to a present-value basis. A value of DR = 0 can be used for analysis without discounting.

NWC. A flag for telling the program which warranty concept is selected:

- NWC = 1, for warranty at the organizational, intermediate, and depot level
- NWC = 2, for warranty at the intermediate and depot level
- NWC = 3, for warranty at the depot level only

(continued)

Table A-2. (continued)

CFCMHD. The contractor's average corrective maintenance man-hours per month for the depot. This is a fixed input that is considered to be a minimum, regardless of the demands of the system. The model compares this value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower has been allocated to corrective maintenance.

AFCMHD. The Air Force average corrective maintenance man-hours per month for the depot. This is a fixed input that is considered to be a minimum, regardless of the demands of the system. The model compares this value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower has been allocated to corrective maintenance.

CALRCM(1),(2),(3).*† The contractor's average labor rate in dollars per man-hour for corrective maintenance for the three maintenance levels. CALRCM(1) is for the organizational level, CALRCM(2) is for the intermediate level, and CALRCM(3) is for the depot.

AALRCM(1),(2),(3).*† The Air Force average labor rate in dollars per man-hour for corrective maintenance for the three maintenance levels.

CCMML(1),(2),(3).* The contractor's average corrective maintenance man-hours for a subassembly action for each of the three maintenance levels.

ACMMLO(1),(2),(3).* The Air Force average corrective maintenance man-hours for a subassembly action for each of the three maintenance levels under organic maintenance.

ACMMLW(1),(2).* The Air Force average corrective maintenance man-hours for a subassembly action for the organizational and intermediate levels when a warranty is in existence.

CCMMM(1),(2),(3).* The contractor's average corrective maintenance man-hours for a module action for each of the three maintenance levels.

ACMMMO(1),(2),(3).* The Air Force average corrective maintenance man-hours for a module action for each of the three maintenance levels under organic maintenance.

ACMMMW(1),(2).* The Air Force average corrective maintenance man-hours for a module action for the organizational and intermediate maintenance levels when a warranty is in existence.

CFPMMD. The contractor's average preventive maintenance man-hours per month for the depot. This is a fixed input that is considered to be a minimum, regardless of the demands of the system. The model compares this value with a demand-driven value and selects the larger of the two. This parameter can be set equal to zero if no fixed manpower is allocated to preventive maintenance.

*Three levels; 1 = Organizational, 2 = Intermediate, 3 = Depot.
†See Subsection 2.3.2 of this appendix for derivation of corrective maintenance labor rates.

(continued)

Table A-2. (continued)

AFPMMD. The Air Force average preventive maintenance man-hours per month for the depot. This parameter is the counterpart to CFPMMD, and it can be set equal to zero if no fixed manpower is allocated to preventive maintenance.

CALRPM(1),(2),(3).*† The contractor's average labor rate in dollars per man-hour for preventive maintenance for the three maintenance levels.

AALRPM(1),(2),(3).*† The Air Force average labor rate in dollars per man-hours for preventive maintenance for the three maintenance levels.

PMRO(1),(2),(3).*†† Preventive maintenance service on the system for each maintenance level under organic maintenance.

PMRW(1),(2),(3).*†† Preventive maintenance service on the system for each maintenance level when a warranty is in existence.

AGBO. Acquisition cost of base AGE (organic maintenance). The cost per base to purchase the base test equipment necessary to support the installed equipment under organic maintenance.

AGBW. Acquisition cost of base AGE (warranty). The cost per base to purchase the base test equipment necessary to support the installed equipment while it is under warranty. Generally, AGBW will be less than AGBO because base test equipment under warranty usually will involve a simple Go/No-Go test, while such equipment under organic maintenance may also include the capability for fault diagnosis to the module level. (Note that the parameter is affected by NWC.)

AGDO. Acquisition cost of depot AGE (organic maintenance). The cost to purchase test equipment for depot maintenance.

PAGB. Annual base AGE support cost factor. The fraction of base AGE acquisition cost that is spent annually to maintain and support the base test equipment.

PAGD. Annual depot AGE support cost factor. The fraction of depot AGE acquisition cost that is spent annually to maintain and support the depot test equipment.

TCPW. Training cost per man-week. The loaded cost to train government personnel for equipment maintenance.

WTBO. Man-weeks of training of base maintenance personnel (organic maintenance). The number of man-weeks of training per base required for base maintenance personnel (organizational and intermediate levels) under organic maintenance.

*Three levels; 1 = Organizational, 2 = Intermediate, 3 = Depot

†See Subsection [illegible] of this appendix for derivation of preventive maintenance labor rates.

††See Subsection 2.3.3 of this appendix for derivation of preventive maintenance service.

(continued)

Table A-2. (continued)

WTDO. Man-weeks of training of depot maintenance personnel (organic maintenance). The number of man-weeks of training required for depot maintenance personnel.

WTBW. Man-weeks of training per base for base maintenance personnel (warranty). Same as WTBO except for maintenance under warranty. (Note that this parameter is affected by NWC.)

RTP. Recurring training factor (organic and warranty). The fraction of initial training cost that is spent annually for recurring training.

DTAO. Data cost (organic maintenance). The cost to acquire all pertinent and identifiable data associated with acquisition under organic maintenance.

DTAW. Data cost (warranty). The cost to acquire all pertinent and identifiable data associated with acquisition under a warranty. (Note that this parameter is affected by NWC.)

RSK. Contractor warranty yearly risk factor. The factor to be applied to all estimated warranty costs to cover contractor risks in warranty pricing. The risk factor for a warranty of TW years is calculated as a compounded rate equal to $(1 + RSK)^{TW}$. If a bid price is used, RSK must be set equal to zero.

PFT. Contractor warranty profit factor. The factor to be applied to all estimated warranty costs to cover the contractor's warranty profit. Total warranty profit is equal to Warranty Cost × PFT. If a bid price is used, PFT can be set equal to zero.

OWF. Factor for noncovered failures under warranty. The factor to apply to all estimated contractor warranty costs to cover payment for repair services for unit failures not covered under the warranty. This payment is calculated as Warranty Cost × OWF. The value of OWF will depend on the extent of the warranty exclusions and other specific warranty terms and conditions.

DTP. Factor for data and other warranty costs. The multiplier factor to be applied to all estimated warranty costs to include the contractor's data costs, administrative costs, and other costs related to performing warranty services. (See COTHW and YCOTHW for alternative inputs to cover "other" contractor costs.) DTP can be set equal to 0 if a warranty bid price is to be used.

RIWPP. Contractor fixed cost, i.e., fixed cost that is not included in overhead. If a contractor gives a bid price, RIWPP is the bid price and RSK must be set equal to zero. (Note that this parameter is affected by NWC.)

YCOTHW. Contractor other yearly cost (warranty). Yearly cost for performing warranty services that are not included elsewhere. (Note that this parameter is affected by NWC.)

(continued)

Table A-2. (continued)

NPCO. Number of P-coded items (organic maintenance). The number of new P-coded or FSN items to be introduced into the inventory under organic maintenance.

NPCW. Number of P-coded items (warranty). The number of new P-coded or FSN items to be introduced into the inventory under warranty.

CIM. Annual inventory management cost. The yearly cost for inventory management of each new P-coded item in the inventory.

OTHO. Other costs (organic maintenance). All other costs incurred under organic maintenance at the time of equipment acquisition.

OTHW. Other costs (full warranty). All other costs incurred under a full warranty at the time of equipment acquisition. (Note that this parameter can be affected by NWC.)

OTHWO. Other costs (warranty/organic). All other costs incurred under a warranty/organic maintenance concept at the time of equipment acquisition. (Note that this parameter can be affected by NWC.)

YOTHO. Yearly other costs (organic maintenance). Yearly costs under organic maintenance not included in any other category.

YOTHW. Year other costs (warranty). Yearly costs under a warranty that are not included in any other category. (Note that this parameter can be affected by NWC.)

CTRANS. Costs of transition. Costs incurred at the time of transition from warranty to organic maintenance that are not included in any other category. (Note that this parameter can be affected by NWC.)

GSET. Guaranteed equipment MTBF value. The value of the guaranteed equipment MTBF if there is such a clause in the contract. If there is a growth factor (i.e., the guarantee value increases with time), the guaranteed MTBF value for the last time period should be used. Let GSET = 0 if there is no MTBF guarantee clause.

TG. The number of years of operation applicable for the MTBF guarantee value. Let TG = 0 for no MTBF guarantee clause.

PCTGW. The percentage of growth in MTBF between 1,000 and 50,000 hours of operation for a system under warranty (i.e., if the growth is considered to be 10 percent of the initial MTBF, then enter 0.10).

PCTGO. The percentage of growth in MTBF between 1,000 and 50,000 hours of operation for a system under organic maintenance (similar to PCTGW).

PLIM. The ultimate growth of MTBF for both organic and warranty. This parameter is entered as a percentage increase (i.e., if the growth is considered to be 20 percent of the initial MTBF, then enter 0.20).

NPX.* The number of different types of bases.

*For a more detailed explanation, see Subsection 3.3 of this appendix.

(continued)

Table A-2. (continued)

NB(K).* The number of systems per base for base type K.

HM(K).* Operating hours per month per installation for base type K.

NBY(K).* The number of years over which the installations will be delivered for base type K.

NSCH(1,K).* The initial number of bases activated at start of the life cycle for base type K.

NSCH(J,K).* The number of bases activated on a yearly basis for base type K. These inputs must be entered in five consecutive-year intervals (i.e., J = 2 through 6, J = 7 through 11, etc.). For each line of data, all five entries are required; e.g., if the schedule is 10 after year 1, 5 after year 2, then the entry would be 10, 5, 0, 0, 0.

CFCMHB(1,K). The contractor's fixed corrective maintenance man-hours for organizational level maintenance per month per base type K. This fixed input is considered a minimum regardless of the demands of the system. This value is compared with a calculated demand-driven corrective maintenance in the model, and the larger value is chosen. If a fixed manpower loading is unknown or not desired, the parameter can be set to zero. This parameter is entered for each type of base.

CFCMHB(2,K). The contractor's fixed corrective maintenance man-hours for intermediate level maintenance per month per base type K. This parameter has the same constrains as CFCMHB(1,K).

AFCMHB(1,K). The Air Force fixed corrective maintenance man-hours for organizational level maintenance per month per base type K. This parameter has the same constraints as CFCMHB(1,K).

AFCMHB(2,K). The Air Force fixed corrective maintenance man-hours for intermediate level maintenance per month per base type K. This parameter has the same constraints as CFCMHB(1,K).

CFPMMB(1,K). The contractor's fixed preventive maintenance man-hours for the organizational level maintenance per month per base type K. This fixed input is considered a minimum value regardless of the demands of the system. This value is compared with a calculated demand-driven preventive maintenance in the model, and the larger value is chosen. If a fixed manpower loading is unknown or not desired, this parameter can be set equal to zero. This parameter is entered for each type of base.

CFPMMB(2,K). The contractor's fixed preventive maintenance man-hours for the intermediate level maintenance per month per base type K. This parameter has the same constraints as CFPMMB(1,K).

AFPMMB(1,K). The Air Force fixed preventive maintenance man-hours for the organizational level maintenance per month per base type K. This parameter has the same constraints as CFPMMB(1,K).

AFPMMB(2,K). The Air Force fixed preventive maintenance man-hours for the intermediate level maintenance per month per base type K. This parameter has the same constraints as AFPMMB(1,K).

*For a more detailed explanation, see Subsection 3.[illegible] of this appendix.

3.2 Equipment Data File

The equipment data file contains data that are dependent on the subassembly or module. It includes cost, reliability, and type of module.

Table A-3 is a list of the required contents of the equipment data file. Program line numbers 2690, 2700, and 2730 are statement line numbers in the computer program that read the equipment file. Each of these data elements is defined as follows:

- NLRU. The number of subassemblies in the equipment. Each subassembly is counted separately, even if two are identical.
- NMOD(J). The number of module types in the j^{th} subassemblies. Two or more identical modules in a subassembly are counted as one module type. If there are no modules in the subassembly, set NMOD(J) equal to 1 and complete the required module data, treating the subassembly as a module.
- CL(J). The acquisition cost of a spare j^{th} type subassembly (organic maintenance). This is the average cost of purchasing a spare j^{th} unit. (Note: If there are no modules in the subassembly, set CL(J) equal to 0.)
- CLW(J). The acquisition cost of a spare j^{th} type subassembly (warranty). (Note: If CL(J) is zero, then CLW(J) is set to zero for the "no module" case.)
- TSP(J). Target spares percentage for j^{th} type subassemblies. This data element applies only when an MTBF guarantee clause is in the contract. TSP(J) × number of units installed is equal to the maximum contractor's liability for providing loaner or consignment spares under the MTBF guarantee provision. For no MTBF guarantee provision, TSP(J) can be set equal to 0.
- CINSO(J). Acquisition cost of installed j^{th} type subassembly (organic maintenance).
- CINSW(J). Acquisition cost of installed j^{th} type subassembly (warranty).
- N_Z(I,J). Module quantity. This data element is the number of modules of the i^{th} type in the j^{th} subassembly.
- XBF(I,J). Initial module MTBF (organic maintenance). The MTBF of the i^{th} type module in the j^{th} subassembly before any MTBF growth factors are introduced.
- IDF(I,J). [illegible]. If the i^{th} module in the j^{th} subassembly [illegible] expendable (e.g., discard-at-failure, throwaway, etc.), [illegible] equal to [illegible]. If the module [illegible] repairable, [illegible].
- [illegible]. The average acquisition cost for the i^{th} module in [illegible].

Symbol	Input Data Elements	
Table A-3. CONTENTS OF EQUIPMENT DATA FILE		
L1	NLRU	
	For j^{th} Subassembly	
L1	NMOD (J), CC (J), CLW (J), TSP (J)	for j^{th} subassembly
L1	CINSO (J), CINSW (J)	
L1	NQ (1,J), XBF (1,J), IDF (1,J), C (1,J)	1st module in j^{th} subassembly
L1	NQ (2,J), XBF (2,J), IDF (2,J), C (2,J)	2nd module in j^{th} subassembly, etc.
	. . .	

3.3 Installation Schedule and Operating Hours

To account for the fact that all the equipment will not be installed at the initiation of a life cycle, the model has incorporated an installation schedule. An integral part of the installation schedule is what has been designated as a base type. A base type is a set of bases that has the same number of systems installed and that operates the same average number of hours per month. The model is structured to account for installations before the start of the life cycle and then to account for scheduled installations for up to 20 years. The scheduled installations must be inputted in [illegible] of five consecutive years at specified intervals, which will be addressed later in this subsection. To visualize the installation schedule, consider the following example:

100 bases with 280 systems installed and operated as follows:

60 bases have two systems per base; of these

30 bases operate their equipment [illegible] hours per day and

30 bases operate their equipment 24 hours per day

40 bases have four systems per base; of these

[illegible] bases operate their equipment [illegible] hours per [illegible] and

[illegible] bases operate their equipment [illegible] hours per day

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From the above example, there are four base types:

Base Type	Systems per Base	Operating Hours per Month per System
1	2	240
2	2	720
3	4	240
4	4	720

An installed base is defined as a base that has installed all of its systems. Thus if a base is scheduled to have four systems but only three have been installed, it is not considered an installed base. This deficiency can be overcome by averaging and will become more apparent as the installation schedule is now addressed.

The installation schedule is as follows:

- Base Type 1: No initial installations. Six installed bases (two each base) for the first five years.
- Base Type 2: No initial installations. Six installed bases (two each base) for five consecutive years starting in year four.
- Base Type 3: No initial installations. Two installed bases (four each base) per year for ten years.
- Base Type 4: No initial installations. Four installed bases (four each base) every other year starting with the first year.

With this information, an installation schedule for the model can be developed, as shown in Table A-4.

Table A-4. INSTALLATION SCHEDULE

Base Type	Systems per Base	Operating Hours per Month per System	Installed Bases After Year										
			0	1	2	3	4	5	6	7	8	9	10
1	2	240	0	6	6	6	6	6	-	-	-	-	-
2	2	720	0	0	0	0	6	6	6	6	6	0	0
3	4	720	0	2	2	2	2	2	2	2	2	2	2
4	4	720	0	4	0	4	0	4	0	4	0	4	0

The information for "Installed Bases After Year" deserves further explanation. The "0" column indicates that initially no systems are installed. The "6" under Year 1 indicates that during the first year 6 type-1 bases

Table A-3. CONTENTS OF EQUIPMENT DATA FILE		
Symbol	Input Data Elements	
L1	NLRU	
	For j^{th} Subassembly	
L1	NMOD (J), CC (J), CLW (J), TSP (J)	for j^{th} subassembly
L1	CINSO (J), CINSW (J)	
L1	NQ (1,J), XBF (1,J), IDF (1,J), C (1,J)	1st module in j^{th} subassembly
L1	NQ (2,J), XBF (2,J), IDF (2,J), C (2,J)	2nd module in j^{th} subassembly, etc.
	⋮ ⋮	

3.3 Installation Schedule and Operating Hours

To account for the fact that all the equipment will not be installed at the initiation of a life cycle, the model has incorporated an installation schedule. An integral part of the installation schedule is what has been designated as a base type. A base type is a set of bases that has the same number of systems installed and that operates the same average number of hours per month. The model is structured to account for installations before the start of the life cycle and then to account for scheduled installations for up to 20 years. The scheduled installations must be inputted in groups of five consecutive years at specified intervals, which will be addressed later in this subsection. To visualize the installation schedule, consider the following example:

100 bases with 280 systems installed and operated as follows:

- 60 bases have two systems per base; of these
  - 30 bases operate their equipment 8 hours per day and
  - 30 bases operate their equipment 24 hours per day
- 40 bases have four systems per base; of these
  - 20 bases operate their equipment 8 hours per day and
  - 20 bases operate their equipment 24 hours per day

installed their equipment; i.e., 12 systems were installed, (2 each at 6 different bases) with the equipment operating 240 hours per month at each base. Similarly, the "4" under Year 1 indicates that during the first year, 4 type-4 bases installed their equipment; i.e., 16 systems were installed (4 each at 4 different bases) with the equipment operating 720 hours per month at each base.

The method for entering the schedule into the model is presented in Figure A-3. Additional explanatory comments are provided following this figure.

It should be noted that the value for NBY(2) for Base Type 2 is equal to 8 even though the example originally stated that the installation period was for 5 consecutive years. The reason for this is because the computer model is expecting to see sets of 5 years of input starting at Year 1. The computer interprets the first 3 years for Base Type 2 as input years, which happens to be zero. Therefore, the value that is entered for NBY is the last year in which there are sites activated.

Secondly, the computer expects to see data in each five-year group. Referring to Base Type 2 again, notice that two groups of five were entered. The first group was Years 1 through 5 and the second group was Years 6 through 10. Years 9 and 10 were entered as zero (0). The computer expects to see data in Years 9 and 10.

The data entered into the general data file would have the following form for this example:

Line Number	Data
280	2, 240., 5, 0
290	6, 6, 6, 6, 6
300	2, 720., 8, 0
310	0, 0, 0, 6, 6
320	6, 6, 6, 0, 0
330	4, 240., 10, 0
340	2, 2, 2, 2, 2
350	2, 2, 2, 2, 2
360	4, 720., 9, 0
370	4, 0, 4, 0, 4
380	0, 4, 0, 4, 0

Base Type 1

NB(1)	HM(1)	NBY(1)	NSCH(1,1)	
2	240.	5	0	
NSCH(2.1)	NSCH(3,1)	NSCH(4,1)	NSCH(5,1)	NSCH(6,1)
6	6	6	6	6

Base Type 2

NB(2)	HM(2)	NBY(2)	NSCH(1,2)	
2	720	8	0	
NSCH(2,2)	NSCH(3,2)	NSCH(4,2)	NSCH(5,2)	NSCH(6,2)
0	0	0	6	6
NSCH(7,2)	NSCH(8,2)	NSCH(9,2)	NSCH(10,)	NSCH(11,2)
6	6	6	0	0

Base Type 3

NB(3)	HM(3)	NBY(3)	NSCH(1,3)	
4	240	10	0	
NSCH(2,3)	NSCH(3,3)	NSCH(4,3)	NSCH(5,3)	NSCH(6,3)
2	2	2	2	2
NSCH(7,3)	NSCH(8,3)	NSCH(9,3)	NSCH(10,3)	NSCH(11,3)
2	2	2	2	2

Base Type 4

NB(4)	HM(4)	NBY(4)	NSCH(1,4)	
4	720.	9	0	
NSCH(2,4)	NSCH(3,4)	NSCH(4,4)	NSCH(5,4)	NSCH(6,4)
4	0	4	0	4
NSCH(7,4)	NSCH(8,4)	NSCH(9,4)	NSCH(10,4)	NSCH(11,4)
0	4	0	4	0

Figure A-3. INPUT DATA AND VARIABLES FOR INSTALLATION SCHEDULE

4. OPERATING INSTRUCTIONS

4.1 Initial Operation

Operation of the computer program requires that the data developed in the format specified in Section 3 be entered into the time-sharing as files. The files should be labeled as follows:

- Equipment Data (EDATA)
- General Data (GDATA)

The model has been labeled WGLCC. Using the CDC time-sharing system, the following procedure will initiate execution of the computer model:

- FTNTS, OLD, WGLCC   R*
- GET, TAPE1 = GDATA   R
- GET, TAPE2 = EDATA   R
- RUN   R

Following each command, the user must wait until the system tells him "READY". The above sequence of commands will employ the source code version of the program (stored in file WGLCC) with the two data sets (GDATA and EDATA), compile the source program, and execute. As the computer commences execution, the terminal will respond with the following:

ORGANIC VS WARRANTY LCC ANALYSIS FILES

CALLED? 0 for No, 1 for Yes

The program is ready to run.

If the program is stored in object code, an alternative method would be to run in the batch mode using the CDC system. The batch mode offers lower cost and should be considered if a large number of analyses are required.

Figure A-4 presents the sequence that is required to utilize the batch features.

A procedural file labeled PWGLCC has been constructed that performs the sequence listed in Figure A-4. To run the program with the data files GDATA and EDATA, simply type in - PWGLCC.

4.2 Interactive Features

After the initial sign-on (described in Subsection 4.1), a series of interactive features are accountable to control the model operation. These features are exercised by the input terminal through operator command.

---

*Symbol R denotes striking the carriage return key after making entry shown.

1. Type In: Batch R
2. The computer will respond with a: /
3. This is a prompt for the user. Type in: GET, BWGLCC R
4. The computer will respond with another /. Type in: GET, TAPE1=GDATA R
5. The computer will respond with another /. Type in: GET, TAPE2=EDATA R
6. The computer will respond with another /. Type BWGLCC R
7. The computer will respond with another /. Type in BWGLCC R

Figure A-4. SEQUENCE TO EXECUTE THE COMPUTER PROGRAM IN BATCH MODE

Each terminal input request includes a printout that summarizes the information required, followed by a line feed, and then a question mark. The required data input is then typed in, followed by a carriage return. For data entries involving more than one value, commas or blanks can be used as separators. If an incorrect value is entered, the break key should be pressed to erase the data submitted. The correct data can then be entered as required.

4.2.1 Program Start

After an initial heading is printed, the computer asks if the two data files have been called. A 0 (zero) is typed in for no, and a 1 (one) is typed in for yes. For the no case, the computer then asks for the File 1 name. This name must be typed in the first seven positions following the question mark, followed by a carriage return. The File 2 name is then requested and is also typed in the first seven positions following the question mark.

4.2.2 Print Input Files

The terminal will request whether you want to print the General Data File and/or the Equipment File. The prompts will be:

DO YOU WANT GENERAL DATA FILE PRINTED,

1-YES, 0-NO

DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO

For those files you want printed, type in a 1. For those files you do not want printed, type in a 0.

4.2.3 IPT Input

The following IPT input is used to define the degree to which cost data for calculated spares are outputted:

IPT = -1: No details on spares costs are printed except total values.

IPT = 0: Subassembly data and summary module data are printed.

IPT = 1: Subassembly and detailed module data are printed.

4.2.4 Warranty Period Data

Warranty period data include the warranty coverage periods that are to be considered. The request is

Warranty Periods - TW, DEL, NP

where

TW = initial warranty period (years)

DEL = increment to initial warranty period

NP = number of warranty periods

Therefore, if warranty periods of 2, 4, 6, 8, and 10 years are to be considered, the input would be 2, 2, 5. If NP is greater than 1, only summary LCC information is outputted. If NP is equal to 0 or 1, the only warranty period to be analyzed will be for TW years, and a detailed LCC output will be printed (including warranty spares data if IPT is 0 or 1). For example, if detailed data for a five-year warranty are required, the terminal input is 5, 0, 0.

4.2.5 Warranty Module Spares Printout

A request is made for printing the warranty spares for each module in each subassembly. To print this information, input a "1". If this information is not desired, input a "0".

4.2.6 Flag for Too High NRTS

If a NRTS rate is chosen so that the NRTS and the Retest OK rates are greater than one, the model flags this fact, sets the NRTS rate so that the new NRTS and the Retest OK are equal to one, and prints out a warning message to the user such as:

NRTS IS TOO HIGH FOR MODULES, WARRANTY

This message states that the value entered for PNRTSMW was such that when added to RTOKM, it resulted in a value greater than 1.

4.2.7 Data Changes

After an LCC run is performed, the following request is made:

INPUT CODE

This code is symbolized by KFLAG in the program and has the following definitions:

Value of KFLAG	Definition
-1	Branch to beginning of LCC analysis and skip input file read statements.
0	Branch to request for warranty coverage period data.
1	Input data file names and then branch to beginning of LCC analysis.
>1 but <99	Branch to a data change routine; following input of data changes, a request for another code value is made so that multiple changes are possible.
>99	Stops execution.

A value of KFLAG = -1 is therefore used when a data change will affect LCC organic maintenance. A value of KFLAG = 0 is used when a different warranty coverage period is to be analyzed or a prior data change will not affect LCC organic maintenance. Table A-5 summarizes the codes for data changes. If a parameter is underlined, it indicates that if the parameter value has been changed, a branch to the beginning of the LCC analysis is required.

An example of a change that will always require a branch to the beginning is Code 2, in which either the MTBFs or Retest OK rates, or both, are to be changed. An example of a code that may require a branch back to the beginning is Code 26, in which values of PCTGW, PCTGO and PLIM are inputted. If only the PCTGW value is changed, the branch can be made to the beginning of the warranty analysis, assuming that no other changes affecting organic maintenance costs have been made.

When a change code is requested, the model will print the parameter names requested for change. It will then print the current value of the parameters below the printed names. The analyst can then change any one or all of the parameters, but the analyst must always enter a value for each parameter shown even if it is the same value.

This feature provides the analyst with a great capability. However, caution must be exercised when employing this capability, since many of these parameters are conditional inputs. In particular, the parameter NWC that states which warranty concept is being employed influences several input parameters. The parameters that are influenced by NWC can be divided

Table A-5. SUMMARY OF DATA CHANGE CODES

Code, K	Data Change
2	MTBF Factor and Retest OK Rates: VFAC*, RTOKS, RTOKM
3	Not-Repairable-This Station Rates: PNRTSSO, PNRTSSW, PNRTSMO, PNRTSMW
4	Probabilities of Demand at Organizational Level: PSO, PSW
5	Probabilities of Maintenance Repair at Organizational Level: POSO, POSW, POMO, POMW
6	Base-Cycle-Repair Times and Order and Ship Times: TBRCO, TBRCW, TOSS, TOSM
7	Depot-Repair-Cycle Times: TDRCSO, TDRCSW, TDRCMO, TDRCMW
8	Spares Cost Data: BMORT, VMOD, PUDAF
9	Contractor Average Labor Rate for Corrective Maintenance: CALRCM(1), CALRCM(2), CALRCM(3)
10	Air Force Average Labor Rate for Corrective Maintenance: AALRCM(1), AALRCM(2), AALRCM(3)
11	Contractor Corrective Maintenance Man-Hours on Subassemblies: CCMML(1), CCMML(2), CCMML(3)
12	Air Force Corrective Maintenance Man-Hours on Subassemblies under Full Organic Maintenance: ACMMLO(1), ACMMLO(2), ACMMLO(3)
13	Air Force Corrective Maintenance Man-Hours on Subassemblies under Warranty: ACMMLW(1), ACMMLW(2)
14	Contractor Corrective Maintenance Man-Hours on Modules: CCMMM(1), CCMMM(2), CCMMM(3)
15	Air Force Corrective Maintenance Man-Hours on Modules under full organic maintenance: ACMMMO(1), ACMMMO(2), ACMMMO(3)
16	Air Force Corrective Maintenance Man-hours on Modules under Warranty: ACMMMW(1), ACMMMW(2)
17	Contractor Average Labor Rate for Preventive Maintenance: CALRPM(1), CALRPM(2), CALRPM(3)
18	Air Force Average Labor Rate for Preventive Maintenance: AALRPM(1), AALRPM(2), AALRPM(3)
19	Preventive Maintenance Rate, Organic: PMRO(1), PMRO(2), PMRO(3)
20	Preventive Maintenance Rate, Warranty: PMRW(1), PMRW(2), PMRW(3)
21	RIW Drive Variables: RSK, PFT, OWF, DTF, RIWFP, YOOTHW
22	Inventory Management Data: NPCO, NPCW, CIM
23	Government "OTHER" Costs: OTHO, OTHW, OTHWO, YOTHO, CTRANS
24	MTBF Guaranty Data: GSET, TG
25	MTBF Growth Data: PCTGW, PCTGO, PLIM
26	Spares Reliability, LCC Period, Discount Rate, Warranty Type: PSUFF, NY, DR, IWC
27	Test Good Probabilities at the Depot: TGDSO, TGDSW, TGDMO, TGDMW

*Each MTBF is multiplied by VFAC.

into two categories. The first category is a set of parameters that might be affected, and the program does not compensate for the effect of NWC. A list of these parameters is as follows:

PNRTSSW	PNRTSMW	PSW	POSW
POMW	TBRCW	TBRCSW	TDRCMW
AGBW	WTBW	DATW	RIWFP
YCOTHW	NPCW	OTHW	OTHWO
YOTHW	CTRANS	OWF	TGDSW
TGDMW			

Some parameters are influenced more than others and some may not be influenced at all.

The second category of parameters that may be influenced by NWC are as follows:

CFCMHD	CCMML(M)	ACMMLW(M)	CCMMM(M)
ACMMMW(M)	CFPMMD	PMRW(M)	AGBW
AFPMMB(M,K)	AFCMHB(M,K)	CFCMHB(M,K)	CFPMMB(M,K)

The reason that these parameters may or may not be influenced by the selection of NWC is the fact that the computer does not use all of these parameters all of the time. Depending on the value of NWC, the economic model will assign the cost to either the Air Force or the contractor. For instance, the parameter CCMML(M) is the contractor's corrective maintenance man-hours for action on a subassembly at each level of maintenance (M = 1, 2, 3). If warranty exists only at the depot level, then CCMML(1) and CCMML(2) are not utilized in the economic model. However, the analyst who considers analyzing the remaining two types of warranty could enter the appropriate data in CCMML(1) and CCMML(2). Likewise, the analyst can enter the total data set for the remaining parameters in the second category.

4.2.8 LCC Model Output

The major output of the model is the calculated life-cycle costs for the organic maintenance and warranty alternatives. In addition, specific details are provided in the following subsections, some of which must be requested by the user.

4.2.8.1 Input Files

The user is prompted as to whether he desires to print the general or equipment input data files. If a print option is selected, the file is printed with the line numbers assigned to each respective line of data. Each line of the data file is printed as a line of output. Thus the output has the same form as the file.

4.2.8.2 Initial Output

After the LCC data and equipment data files are read in, a printout of initial equipment and subassembly MTBFs, under organic maintenance, is furnished, together with the cost of subassembly spares. In addition, the initial organic system MTBF and false pull rate are printed. Later, in the warranty section, the false pull rate for warranty is printed.

4.2.8.3 Organic MTBF

The average MTBF over the life-cycle period is printed for the organic maintenance alternative.

4.2.8.4 Organic Spares Data

If a print code value of IPT = 1 is inputted, organic spares requirements for both subassemblies and modules are provided. A print code value of IPT = 0 includes details only for subassemblies and a summary of the module spares costs. A print code value of IPT = -1 will not include detailed sparing data.

4.2.8.5 Installation Schedule and Operating Hours

The operating hours per month and the installation schedule is printed for each base type. The first line of output for each base type contains the base type number, the number of installations per base type, the operating hours per installation per month, the number of bases that have their complete set of installations at the beginning of the life-cycle years, and the number of bases that have completed their installation schedule for five consecutive years. If a base type has installations in the sixth year or after, these installations are printed in five-year intervals until the entire schedule is completed. Each line will have five consecutive years and is printed below the first five consecutive years of installation. This output form is repeated for each base type.

4.2.8.6 Warranty Spares Data

If the print code value is 0 or 1 and the run involves only one warranty period, subassembly spares requirements under warranty are provided, as well as spares cost factors applicable at transition from warranty to organic maintenance. For each sparing level, subassembly, repairable module, and discard-at-failure module, three cost factors are included:

- Requirement cost
- Value of excess warranty spares
- Net cost

The requirement cost factor has different meanings for subassemblies and modules. For subassemblies it is the cost of the RIW spares purchased. For modules it is the cost to support the follow-on organic maintenance, appropriately discounted.

The value factor represents the discounted value of any excess spare equipment available at transition time. For example, if required organic sparing for a subassembly is 200 units and 300 spares are required under warranty, the value factor represents the value of the 100 extra subassemblies distributed appropriately among complete subassemblies, repairable modules, and discard-at-failure modules.

The net cost represents the difference between the requirement and the value of excess warranty spares. The sum of the net costs for subassemblies, repairable modules, and discard-at-failure modules represents the total spares cost for a warranty/organic maintenance support concept.

In addition, the user can select a detailed printout of the warranty module spares. This output prints the number of module spares for each module in each subassembly and gives the percentage of initial installation for this sparing level.

4.2.8.7 Discount Factors

When warranty spares data for a warranty period of TW years are outputted, they are followed with the following discount factor data:

- DSC1 - The average discount factor over the warranty period
- DSCTW - The discount factor at time of transition
- DSC2 - The average discount factor over the period of organic maintenance following transition
- DSCTOT - The average discount factor over the life cycle

4.2.8.8 Life-Cycle Costs, Summary Print

If more than one warranty period is being considered (a terminal input value of NP>1), only summary life-cycle costs are outputted. The total life-cycle costs under organic maintenance are first printed. Then for each of the candidate warranty periods, the following data are printed:

- RIW LCC - The life-cycle costs under initial warranty followed by organic maintenance
- Savings/Loss - The organic LCC minus the RIW LCC
- RIW Price - The discounted warranty price
- AVG MTBF - The average MTBF value over the life-cycle period

4.2.8.9 Life-Cycle Cost, Detailed Print

When only a single warranty period is being analyzed, the cost factors constituting the total organic and warranty life-cycle costs are printed. In addition, the discounted warranty price, the yearly warranty price as a percentage of installed equipment acquisition cost, and average MTBFs over

(0, TW), (TW, NY), and (0, NY) are also outputted. The individual LCC cost elements were described in Chapter Six, Section 6.3. The only special case is one in which the warranty period being analyzed (TW) coincides with the life-cycle period (NY). In this case, two sets of warranty cost data are presented. The first set, labeled Warranty/Organic, is for the instance in which the life-cycle period does not represent the equipment's useful life. Therefore, costs for additional training, data, AGE, spares, and other elements required at transition are included. Costs for future DAF module requirements are not included since the remaining useful life of the equipment is unspecified. For the costs under Full Warranty, it is assumed that the life-cycle period coincides with the equipment's useful life, and no transition costs are calculated.

5. ILLUSTRATIVE COMPUTER RUNS

A sample problem is presented in this section to illustrate the computer application of the organic versus warranty life-cycle-cost model. We consider the acquisition of a dual system with a high mean time between failures (MTBF), and a low quantity of installations. The system consists of four subassemblies that contain a total of 30 modules. A bonded storeroom concept is used with a module-level warranty. No subassembly will be removed from the organizational level; therefore, sparing will not exist for subassemblies. This sample problem is the same system analyzed in the case study presented in Chapter Nine.

5.1 Inputting the Data

5.1.1 Equipment Data File

The equipment data file contains the detailed description of the system. Figure A-5 is a sample run of the equipment data file, called "QUIP2", developed for the system described above. Some significant points related to the data in this figure are as follows:

- Subassembly 1 and its modules are described in lines 200-240, Subassembly 2 in lines 300-355, Subassembly 3 in lines 400-425, and Subassembly 4 in lines 500-530.
- The cost of each subassembly is the same for both organic and warranty. This similarity is attributable to a policy decision that requires the same amount of testing for warranty as for organic in order to decrease the contractor's risk as much as possible.
- The fourth module in Subassembly 1 is discard-at-failure. This module is described in line 230. The "2" represents the two modules, "100000" hours is the initial module MTBF, "0" denotes discard-at-failure, and the module cost is "500" dollars.
- Subassembly 1 contains one other module type that is duplicated in the subassembly. Subassembly 3 has three modules of the same type, and Subassembly 4 has 2 modules of the same type.

```
10 4
200 6, 15000., 15000., .1
210 15000., 15000.
215 1, 50000., 1, 1000.
220 1, 50000., 1, 2000.
225 1, 50000., 1, 2500.
230 2, 100000., 0, 500.
235 2, 66667., 1, 3500.
240 1, 33333., 1, 1500.
300 10, 20000., 20000., .1
305 20000., 20000.
310 1,125000., 1, 2000.
315 1,250000., 1, 1000.
320 1,83333., 1, 3000.
325 1,166667., 1, 2500.
330 1,100000., 1, 1500.
335 1,100000., 1, 4000.
340 1,250000., 1, 500.
345 1,100000., 1, 2500.
350 1,125000., 1, 2000.
355 1,125000., 1, 1000.
400 4, 40000., 40000., .1
405 40000., 40000.
410 3, 50000., 1, 10000.
415 1,40000., 1, 2500.
420 1, 33333., 1, 5000.
425 1,200000., 0, 2500.
500 5, 25000., 25000., .1
505 25000., 25000.
510 2,200000., 1, 3000.
515 1,500000., 0, 2500.
520 1,200000., 1, 3500.
525 1, 30303., 1, 10000.
530 1,100000., 1, 3000.
READY.
```

Figure A-5. SAMPLE RUN OF EQUIPMENT DATA FILE, "QUIP2"

- Subassembly 3 and Subassembly 4 each contain a discard-at-failure module.

5.1.2 General Data File

The general data file is used to describe equipment acquisition, installation, and support concepts. Figure A-6 is a sample run of the general data file, called "GDF2", developed for this system. Significant points related to the data in this figure are as follows:

- Repairs at the base will consist mainly of isolating a faulty card (a module), replacing it with a spare, and sending the faulty card to the depot for repair. Under warranty, the depot would be the contractor's facility. A subassembly would not be removed from the base.

```
10 .00,.0,.9,.95
20 .05,.05,0.,.05
30 1.0,1.,.05,.05
35 .0 , .0,  .10,   .05
40 8.,5.,12.,12.
50 38.,28.,38.,28.
60 1.,1.,.9
70 .95,10,.1,3
80 0.,0.
90 18.,21.,31.
100 17.,17.,35.
110 1.5,3.,5.
120 2.,4.,6.
130 1.,1.
140 2.,3.,10.
150 2.5,4.,15.
160 1.,2.
170 0.,0.
180 18.,21.,31.
190 17.,17.,35.
200 .015,.000,0.
210 .015,.000,.0
220 15000.,5000.,100000.,.07,.1
230 1040.,4.,15.,2.,.05
240 300000.,50000.
250 .05,.12,.01,.05,250000.,85000.
260 300,35,300.
270 50000.,350000.,0.,0.,30000., 50000.
280 3500.,5.
290 .20,.05,.75,3
300 2,180.,3,0
310 3,1,1,0,0
320 2, 360., 3, 0
330 9,21,15,0,  0
332 4,360.,3,0
334 2,5,3,0,0
340 0.,0.,0.,0.
350 0.,0.,0.,0.
352 0.,0.,0.,0.
360 0.,0.,0.,0.
370 0.,0.,0.,0.
380 0.,0.,0.,0.
READY.
```

Figure A-6. SAMPLE RUN OF GENERAL DATA FILE, "GDF2"

- At the intermediate level, there is a 5 percent probability that a module will Retest OK (line 20, fourth value). Under organic maintenance there is a 90 percent probability that a module will have to be sent to the depot for repair (line 10, third value), leaving a 5 percent probability that it is repaired at the intermediate site. Under module warranty at the depot, a module that does not Retest OK will always be sent to the depot, PNRTSMW = .95 (line 10, fourth value).
- BMORT and VMOD are set equal to 1 for linear depreciation of subassemblies and modules, respectively (line 60).
- Sparing is set to meet a 95 percent spares-sufficiency level, PSUFF = 0.95 (line 70).
- A 10-year life cycle is used, NY = 10; and a 10 percent discount rate is used, DR = 0.1 (line 70).
- NWC is set equal to 3 for depot-level warranty only (line 70).
- All estimated averages for minimum fixed maintenance man-hours per location are set equal to zero.
- The average man-hours per maintenance action are higher for the Air Force than for the contractor and are higher for full organic maintenance than for warranty.
- Preventive maintenance is performed by organizational personnel only and is equal for organic maintenance and warranty.
- The AGE cost is $15,000 per base under organic maintenance and $5,000 per base under warranty contract. Depot AGE cost is $100,000 for organic maintenance. The annual base AGE support cost factor (PAGB) is 7 percent per year, and the annual depot AGE support cost factor is 10 percent (line 220).
- Training, data, and inventory management costs are less under warranty than under organic maintenance. At the time of transition, the difference is calculated and discounted as appropriate.
- A risk factor (RSK) of 5 percent per year and a profit factor (PFT) of 12 percent are used in calculating the warranty price (line 250).
- The contractor incurs a yearly cost of $50,000 YCOTHW, which includes warranty report preparation and publication requirements. The contractor's fixed warranty cost is $250,000, RIWFP (line 250).
- Under warranty, it is assumed that the government incurs a yearly cost of $30,000 for administration and DCAS matters, YOTHW. At transition, a cost of $50,000 is incurred to cover expenses associated with the conversion from warranty to organic maintenance, CTRANS (line 270).
- The equipment has a guaranteed MTBF value of 3,500 hours, GSET, that must be achieved by the end of the fifth year, TG (line 280).

- Under organic maintenance, the MTBF is expected to increase by 5 percent in the first 50,000 hours of operation, PCTGO. It is expected to increase 20 percent under the warranty contract, PCTGW. The upper limit of expected growth is 75 percent for both cases (line 290).
- There are three base types; each base type is described, and its installation schedule given before proceeding to the next base type.
- Fixed man-hours for both corrective and preventive maintenance are assumed to be zero.

5.2 Running the Model

Figure A-7 presents the computer runs that use the data file described in Figures A-5 and A-6. Circled letters in the figure correspond to the following comments:

(A) Files have been previously called and thus a 1 is entered.

(B) The general and equipment data files were printed. The inputs were 1 for each file.

(C) Initial set MTBF and Organic MTBD values of 2500.0 and 2184.1 are calculated and printed, as well as subassembly MTBF and cost of spares.

(D) Installation schedule and operating hours are printed for each base type.

(E) Since the print code was set to equal 1, detailed organic maintenance spares data are printed. First, subassembly spares data are printed, followed by modules spares requirements. Note that subassemblies are not spared and that a minus sign precedes the module number if the module is discarded at failure. A summary of spares cost is then provided.

(F) A request is then made for warranty-coverage-period data. The data input of 1, 1, 10 represents a request for calculating life-cycle costs under warranty, starting with a one-year coverage period and incrementing by one year until 10 warranty periods are considered.

(G) Total ten-year discounted life-cycle costs under organic maintenance is printed, followed by the life-cycle costs under warranty for each of the warranty periods, together with savings/loss, warranty price, and average MTBF.

(H) A request is made for the input code, K flag. A value of 0 is inputted, which causes a program transfer back to the request for values of TW, DEL, and NF. The data values of 5, 0, 0 are inputted, which means that detailed LCC data output for a five-year warranty is desired.

(I) Full details on spares, discounting factors, warranty price, and LCC cost elements are then provided for a warranty period of five years.

(J) Again, a request for a new input code is made. A value of 2 is inputted; this corresponds to a data change for MTBF and/or Retest OK rates. The request for the MTBF factor, VFAC, and the Retest OK rates (RTOKS and RTOKM), is then made, and values of 0.5, 0.0, and 0.05 are inputted. This means that each MTBF is to be multiplied by 0.5 and the Retest OK rates remain the same.

(K) A new input code is then requested. Since changing the MTBF affects organic maintenance, a response of -1 is made so that transfer is returned to the beginning of the analysis of LCC organic maintenance.

(L) A request for warranty coverage period is made, and a response for 10 periods ranging from one year to ten years in increments of one year is given. The LCC output is then provided.

(M) Steps J, K, and L are repeated for an MTBF factor of VFAC = 1.5, which is equivalent to decreasing the initial MTBF by 25 percent.

(N) A response of 99 is made for the input code request, terminating the run.

6. MODEL DETAILS

This section presents the major algorithms utilized by the main program to perform the life-cycle-cost for full organic and warranty followed by organic maintenance.

6.1 Definitions and Equations

Table A-6 is a list of the major equations in the model. For each equation, the computer line number in which the equation is first used in the program is indicated by parentheses. The term "warranty/organic" is used to denote the case in which an initial warranty is to be followed by a transition to organic maintenance. The term "full warranty" is used to denote the case in which the warranty applies to the total life cycle of the equipment without any transition to organic maintenance. Table A-7 presents brief symbol definitions employed by the main program. These definitions are intended for quick "look up" capability only. Detailed definitions of the input parameters are presented in Table A-2.

6.2 Program Diagram and Listing

A functional flow of the program is presented in Figure A-8. Figure A-9 is a detailed listing of the code.

WARRANTY LCC ANALYSIS

FILES CALLED? 0 FOR NO, 1 FOR YES

(A) 1

DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO

1

DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO

1

(B) *GENERAL DATA FILE*

10	0.0000	0.0000	.9000	.9500		
20	.0500	.0500	0.0000	.0500		
30	1.0000	1.0000	.0500	.0500		
35	0.0000	0.0000	.1000	.0500		
40	8.00	5.00	12.00	12.00		
50	38.00	28.00	38.00	28.00		
60	1.0000	1.0000	.9000			
70	.95000	10	.10000	3		
80	0.	0.				
90	18.00	21.00	31.00			
100	17.00	17.00	35.00			
110	1.5000	3.0000	5.0000			
120	2.0000	4.0000	6.0000			
130	1.0000	1.0000				
140	2.0000	3.0000	10.0000			
150	2.5000	4.0000	15.0000			
160	1.0000	2.0000				
170	0.	0.				
180	18.00	21.00	31.00			
190	17.00	17.00	35.00			
200	.0150	0.0000	0.0000			
210	.0150	0.0000	0.0000			
220	15000.	5000.	100000.	.07000	.10000	
230	1040.0000	4.0000	15.0000	2.0000	.0500	
240	300000.	50000.				
250	.05000	.12000	.01000	.05000	250000.	50000.
260	300	35	300.			
270	50000.	0.	0.	0.	30000.	50000.
280	3500.	5.				
290	.20000	.10000	.75000	3		
[illegible]	2	190.00	3	0		
[illegible]	3	1	1	0	0	
[illegible]	2	360.00	3	0		
[illegible]	9	21	15	0	0	
332	4	360.00	3	0		
334	2	5	3	0	0	
340	0.	0.	0.	0.		
350	0.	0.	0.	0.		
352	0.	0.	0.	0.		
[illegible]	0.	0.	0.	0.		
370	0.	0.	0.	.		
[illegible]	0.	0.	0.			

Figure A-7. SAMPLE COMPUTER RUNS OF LCC ORGANIC MAINTENANCE VERSUS WARRANTY

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

```
*EQUIPMENT DATA*
 10          4
200          6     15000.      15000.     .10000
210     15000.     15000.
215          1     50000.          1       1000.
220          1     50000.          1       2000.
225          1     50000.          1       2500.
230          2    100000.          0        500.
235          2     66667.          1       3500.
240          1     33333.          1       1500.
300         10     20000.      20000.     .10000
305     20000.     20000.
310          1    125000.          1       2000.
315          1    250000.          1       1000.
320          1     83333.          1       3000.
325          1    166667.          1       2500.
330          1    100000.          1       1500.
335          1    100000.          1       4000.
340          1    250000.          1        500.
345          1    100000.          1       2500.
350          1    125000.          1       2000.
355          1    125000.          1       1000.
400          4     40000.      40000.     .10000
405     40000.     40000.
410          3     50000.          1      10000.
415          1     40000.          1       2500.
420          1     33333.          1       5000.
425          1    200000.          0       2500.
500          5     25000.      25000.     .10000
505     25000.     25000.
510          2    200000.          1       3000.
515          1    500000.          0       2500.
520          1    200000.          1       3500.
525          1     30303.          1      10000.
530          1    100000.          1       3000.
```

(C)

```
INITIAL SYSTEM MTBF= 2500.0  INITIAL ORGANIC SYSTEM MTBD= 2184.1

 ORGANIC FALSE PULL RATE= .126

SYSTEM COST-ORGANIC•WARRANTY = $ 100000. 100000.

     INITIAL     COST PER SPARE SUB
 SUB   MTBF     ORG.    WRNTY.
  1    7142.8  15000.   15000.
  2   12500.0  20000.   20000.
  3    8333.3  40000.   40000.
  4   16666.7  25000.   25000.
```

(D)

```
   OPERATING HOURS AND INSTALL SCHEDULE BY YEAR FOR EACH BASE TYPE
 BASE  # OF   OF HR     ACTIVATED SITES AFTER N YEARS
 TYPE  SETS   PER MO    0      1      2      3      4      5
   1      2   180.      0      3      1      1      0      0
   2      2   360.      0      9     21     15      0      0
   3      4   360.      0      2      5      3      0      0

  PRINT CODE
5 1
```

Figure A-7. (continued)

TOT.# INSTALLS = 140 TOT.OPER.HRS. = 4896720.

AVERAGE ORGANIC GROWTH MTBF = 3000.0

(E)

ORGANIC MAINTENANCE SPARES

SUB	SPARES	PCT.	COST
1	0	0.00	0.
2	0	0.00	0.
3	0	0.00	0.
4	0	0.00	0.

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	4	2.86
1	2	1	4	2.86
1	3	1	4	2.86
1	-4	2	85	30.36
1	5	2	5	1.79
1	6	1	5	3.57
2	1	1	4	2.86
2	2	1	4	2.86
2	3	1	4	2.86
2	4	1	4	2.86
2	5	1	4	2.86
2	6	1	4	2.86
2	7	1	4	2.86
2	8	1	4	2.86
2	9	1	4	2.86
2	10	1	4	2.86
3	1	3	8	1.90
3	2	1	4	2.86
3	3	1	5	3.57
3	-4	1	21	15.00
4	1	2	4	1.43
4	-2	1	8	5.71
4	3	1	4	2.86
4	4	1	5	3.57
4	5	1	4	2.86

TOTAL COST OF SPARE SUBS = $ 0.
TOTAL COST OF SPARE REP.MODULES= $ 330000.
TOTAL COST OF DAF MODULES = $ 74111.

TOTAL SPARES & DAF MODULE COST= $ 404111.

(F)

WARRANTY PERIODS-TW,DEL,NP
? 1,1,10

WARRANTY AT DEPOT LEVEL

TOTAL ORGANIC LCC = $ 18488754.

(G)

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	18500430.	-11676.	357499.	3288.
2.00	18328300.	160455.	455798.	3406.
3.00	18238145.	250609.	575364.	3468.
4.00	18136934.	351821.	703139.	3500.
5.00	18067538.	421217.	831849.	3518.
6.00	18017403.	471351.	962122.	3529.
7.00	17986984.	501770.	1094427.	3535.
8.00	17975068.	513686.	1229176.	3539.
9.00	17979586.	509165.	1366749.	3541.
10.00	17998353.	490402.	1507916.	3541.
FULL W	17558679.	930075.		

Figure A-7. (continued)

(H)

INPUT CODE
? 0
WARRANTY PERIODS-TW,DEL,NP
? 5,0,0

WARRANTY AT DEPOT LEVEL

INITIAL WARRANTY SYSTEM MTBD= 2280.0
WARRANTY FALSE PULL RATE= .088

(I)

WARRANTY SPARES

SUB	SPARES	PCT.	COST
1	0	0.00	0.
2	0	0.00	0.
3	0	0.00	0.
4	0	0.00	0.

DO YOU WANT MODULE SPARES DATA PRINTED, 1-YES, 0-NO
? 1

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	4	2.86
1	2	1	4	2.86
1	3	1	4	2.86
1	-4	2	28	10.00
1	5	2	4	1.43
1	6	1	4	2.86
2	1	1	4	2.86
2	2	1	4	2.86
2	3	1	4	2.86
2	4	1	4	2.86
2	5	1	4	2.86
2	6	1	4	2.86
2	7	1	4	2.86
2	8	1	4	2.86
2	9	1	4	2.86
2	10	1	4	2.86
3	1	3	5	1.19
3	2	1	4	2.86
3	3	1	4	2.86
3	-4	1	7	5.00
4	1	2	4	1.43
4	-2	1	2	1.43
4	3	1	4	2.86
4	4	1	4	2.86
4	5	1	4	2.86

WARRANTY SPARES COSTS

	SUB	REP.MOD.	DAF MOD.	TOTAL
REQUIRED	0.	280000.	52919.	332919.
AVLE	0.	0.	0.	0.
NET COST	0.	280000.	52919.	332919.

DISCOUNT FACTORS
DISC1,DISCTW,DISC2,DISCTOT .7953 .6209 .4937 .6444

Figure A-7. (continued)

```
 5.0 YEAR WARRANTY PRICE            831849.
PCT/YR PER INSTALLED SET      1.19

                              ORGANIC    WRNTY/ORG    FULL WRNTY
ACQUISTION                   14000000.  14000000.
INITIAL SPARING                330000.    280000.
REPLENISHMENT SPARES            74111.     52919.
CORRECTIVE MAINTENANCE         591507.    265072.
PREVENTIVE MAINTENANCE         742032.    742032.
WARRANTY PRICE                            831849.
AGE                           1000000.    734645.
AGE SUPPORT                    470447.    263705.
TRAINING                       350654.    269521.
DATA                           300000.    205230.
INVENTORY MANAGEMENT           580003.    263926.
MTBF GUARANTEE                                 0.
OTHER                           50000.    158639.

TOTAL                        18488754.  18067538.

AVG.MTBFS: 0 TO  5.0    5.0 TO 10.0  TOTAL
           3395.2       3606.5     3517.9
 INPUT CODE
? 2
 MTBF FACTOR & RETEST OK RATES(RTOKS,RTOKM)
 1. 0. .05
? .5,0.,.05
 INPUT CODE
? -1
  DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO
? 0
  DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO
? 0

INITIAL SYSTEM MTBF= 1250.0  INITIAL ORGANIC SYSTEM MTBD= 1092.1

 ORGANIC FALSE PULL RATE= .126

SYSTEM COST-ORGANIC,WARRANTY = $ 100000. 100000.

     INITIAL    COST PER SPARE SUB
 SUB   MTBF     ORG.    WRNTY.
  1   3571.4  15000.  15000.
  2   6250.0  20000.  20000.
  3   4166.7  40000.  40000.
  4   8333.3  25000.  25000.


  OPERATING HOURS AND INSTALL SCHEDULE BY YEAR FOR EACH BASE TYPE
 BASE   # OF  OP HR     ACTIVATED SITES AFTER N YEARS
 TYPE   SETS  PER MO    0      1      2      3      4      5
  1       2   130.      0      3      1      1      0      0
  2       2   360.      0      9     21     15      0      0
  3       4   360.      0      2      5      3      0      0

  PRINT CODE
? 0

TOT.# INSTALLS =  140  TOT.OPER.HRS. =     4896720.

AVERAGE ORGANIC GROWTH MTBF = 1500.0
```

Figure A-7. (continued)

```
  ORGANIC MAINTENANCE SPARES
SUB   SPARES    PCT.      COST
 1       0      0.00         0.
 2       0      0.00         0.
 3       0      0.00         0.
 4       0      0.00         0.


TOTAL COST OF SPARE SUBS =          $        0.
TOTAL COST OF SPARE REP.MODULES= $ 438000.
TOTAL COST OF DAF MODULES =         $ 149834.

TOTAL SPARES & DAF MODULE COST=  $ 587834.
```

(L)

```
 WARRANTY PERIODS-TW,DEL,NP
? 1,1,10

  WARRANTY AT DEPOT LEVEL

TOTAL ORGANIC LCC = $ 19263984.

WRNTY YRS.       WRNTY LCC    SAVINGS/LOSS  WRNTY  PRICE   AVG.MTBF
   1.00          19202914.        61071.         364935.    1644.
   2.00          18995940.       268045.         490514.    1703.
   3.00          18883361.       380623.         657510.    1734.
   4.00          18762018.       501966.         839638.    1750.
   5.00          17838667.      1425317.        1022162.    1759.
   6.00          17788039.      1475945.        1206222.    1764.
   7.00          17761294.      1502690.        1392523.    1768.
   8.00          17760637.      1503347.        1581722.    1769.
   9.00          17781838.      1482146.        1774396.    1770.
  10.00          17808[illegible]4.      1455910.        1971089.    1771.
FULL W           17368400.      1895584.
 INPUT CODE
? 0
 WARRANTY PERIODS-TW,DEL,NP
? 5,0,0

  WARRANTY AT DEPOT LEVEL

 INITIAL WARRANTY SYSTEM MTBD= 1140.0
 WARRANTY FALSE PULL RATE= .088


WARRANTY SPARES
  SUB   SPARES   PCT.     COST
   1       0     0.00        0.
   2       0     0.00        0.
   3       0     0.00        0.
   4       0     0.00        0.

 DO YOU WANT MODULE SPARES DATA PRINTED, 1=YES, 0=NO
? 1
```

Figure A-7. (continued)

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	4	2.86
1	2	1	4	2.86
1	3	1	4	2.86
1	-4	2	56	20.00
1	5	2	5	1.79
1	6	1	5	3.57
2	1	1	4	2.86
2	2	1	4	2.86
2	3	1	4	2.86
2	4	1	4	2.86
2	5	1	4	2.86
2	6	1	4	2.86
2	7	1	4	2.86
2	8	1	4	2.86
2	9	1	4	2.86
2	10	1	4	2.86
3	1	3	11	2.62
3	2	1	5	3.57
3	3	1	5	3.57
3	-4	1	14	10.00
4	1	2	4	1.43
4	-2	1	5	3.57
4	3	1	4	2.86
4	4	1	5	3.57
4	5	1	4	2.86

WARRANTY SPARES COSTS

	SUB	REP.MOD.	DAF MOD.	TOTAL
REQUIRED	0.	384543.	107825.	492368.
VALUE	0.	0.	0.	0.
NET COST	0.	384543.	107825.	492368.

DISCOUNT FACTORS

DISC1,DISCTW,DSC2,DSCTOT .7952 .6209 .4937 .6444

5.0 YEAR WARRANTY PRICE 1022182.

PCT/YR PER INSTALLED SET 1.46

	ORGANIC	WRNTY/ORG	FULL WRNTY
ACQUISITION	14000000.	14000000.	
INITIAL SPARING	438000.	384543.	
REPLENISHMENT SPARES	149834.	107825.	
CORRECTIVE MAINTENANCE	1183015.	530144.	
PREVENTIVE MAINTENANCE	742032.	742032.	
WARRANTY PRICE		1022182.	
AGE	1000000.	734645.	
AGE SUPPORT	470447.	263705.	
TRAINING	350654.	269521.	
DATA	300000.	205230.	
INVENTORY MANAGEMENT	580003.	253926.	
MTBF GUARANTEE		-645628.	
OTHER	50000.	160542.	
TOTAL	19263984.	17838867.	

Figure A-7. (continued)

```
AVG.MTBFS: 0 TO  5.0    5.0 TO 10.0  TOTAL
               1697.6      1803.2    1759.0
 INPUT CODE
? 2
 MTBF FACTOR & RETEST OK RATES(RTOKS,RTOKM)
 .5 0. .05
? 1.5,0.,.05
 INPUT CODE
? -1
  DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO
? 0
  DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO
? 0

INITIAL SYSTEM MTBF= 1875.0  INITIAL ORGANIC SYSTEM MTBD= 1638.1

 ORGANIC FALSE PULL RATE= .126

SYSTEM COST-ORGANIC,WARRANTY = $ 100000. 100000.

      INITIAL     COST PER SPARE SUB
 SUB   MTBF     ORG.    WRNTY.
  1    5357.1  15000.  15000.
  2    9375.0  20000.  20000.
  3    6250.0  40000.  40000.
  4   12500.0  25000.  25000.


   OPERATING HOURS AND INSTALL SCHEDULE BY YEAR FOR EACH BASE TYPE
 BASE  # OF   OP HR     ACTIVATED SITES AFTER N YEARS
 TYPE  SETS   PER MO    0      1      2      3      4      5
   1      2   180.      0      3      1      1      0      0
   2      2   360.      0      9     21     15      0      0
   3      4   360.      0      2      5      3      0      0

  PRINT CODE
? 1

TOT.# INSTALLS =  140  TOT.OPER.HRS. =     4896720.

AVERAGE ORGANIC GROWTH MTBF = 2250.0

   ORGANIC MAINTENANCE SPARES
 SUB   SPARES    PCT.      COST
  1       0      0.00        0.
  2       0      0.00        0.
  3       0      0.00        0.
  4       0      0.00        0.
```

Figure A-7. (continued)

MODULE SPARES

SUB	MOD	QTY	SPARES	PCT.
1	1	1	4	2.86
1	2	1	4	2.86
1	3	1	4	2.86
1	-4	2	113	40.36
1	5	2	5	1.79
1	6	1	5	3.57
2	1	1	4	2.86
2	2	1	4	2.86
2	3	1	4	2.86
2	4	1	4	2.86
2	5	1	4	2.86
2	6	1	4	2.86
2	7	1	4	2.86
2	8	1	4	2.86
2	9	1	4	2.86
2	10	1	4	2.86
3	1	3	9	2.14
3	2	1	5	3.57
3	3	1	5	3.57
3	-4	1	28	20.00
4	1	2	4	1.43
4	-2	1	11	7.86
4	3	1	4	2.86
4	4	1	5	3.57
4	5	1	4	2.86

TOTAL COST OF SPARE SUBS = $ 0.
TOTAL COST OF SPARE REP.MODULES= $ 342500.
TOTAL COST OF DAF MODULES = $ 99245.

TOTAL SPARES & DAF MODULE COST= $ 441745.

WARRANTY PERIODS-TW,DEL,NF
? 1,1,10

WARRANTY AT DEPOT LEVEL

TOTAL ORGANIC LCC = $ 18723557.

WRNTY YRS.	WRNTY LCC	SAVINGS/LOSS	WRNTY PRICE	AVG.MTBF
1.00	18719221.	4336.	359978.	2466.
2.00	18554508.	169049.	467370.	2555.
3.00	18460335.	263222.	602746.	2601.
4.00	18364897.	358660.	748639.	2625.
5.00	18009702.	713856.	895293.	2638.
6.00	17965184.	758373.	1043485.	2646.
7.00	17929377.	794180.	1193793.	2651.
8.00	17923240.	800317.	1346691.	2654.
9.00	17933392.	790165.	1502631.	2656.
10.00	17957140.	766417.	1662040.	2656.
FULL W	17517466.	1206091.		

INPUT CODE
? 0
WARRANTY PERIODS-TW,DEL,NF
? 5,0,0

Figure A-7. (continued)

```
 WARRANTY AT DEPOT LEVEL

 INITIAL WARRANTY SYSTEM MTBD= 1710.0
 WARRANTY FALSE PULL RATE= .088


WARRANTY SPARES
 SUB   SPARES    PCT.     COST
  1       0      0.00        0.
  2       0      0.00        0.
  3       0      0.00        0.
  4       0      0.00        0.

 DO YOU WANT MODULE SPARES DATA PRINTED, 1-YES, 0-NO
? 1

 MODULE SPARES
 SUB  MOD   QTY    SPARES    PCT.
  1    1     1        4      2.86
  1    2     1        4      2.86
  1    3     1        4      2.86
  1   -4     2       37     13.21
  1    5     2        4      1.43
  1    6     1        4      2.86
  2    1     1        4      2.86
  2    2     1        4      2.86
  2    3     1        4      2.86
  2    4     1        4      2.86
  2    5     1        4      2.86
  2    6     1        4      2.86
  2    7     1        4      2.86
  2    8     1        4      2.86
  2    9     1        4      2.86
  2   10     1        4      2.86
  3    1     3        8      1.90
  3    2     1        4      2.86
  3    3     1        4      2.86
  3   -4     1        9      6.43
  4    1     2        4      1.43
  4   -2     1        3      2.14
  4    3     1        4      2.86
  4    4     1        5      3.57
  4    5     1        4      2.86

 WARRANTY SPARES COSTS
                  SUB     REP.MOD.    DAF MOD.     TOTAL
REQUIRED           0.     326209.      70425.    396635.
VALUE              0.          0.          0.         0.
NET COST           0.     326209.      70425.    396635.

    DISCOUNT FACTORS
DISC1,DISCW,DISC2,DISCTOT   .7952   .6209   .4937   .6444
```

Figure A-7. (continued)

5.0 YEAR WARRANTY PRICE 895293.
PCT/YR PER INSTALLED SET 1.28

	ORGANIC	WRNTY/ORG	FULL WRNTY
ACQUISTION	14000000.	14000000.	
INITIAL SPARING	342500.	326209.	
REPLENISHMENT SPARES	99245.	70425.	
CORRECTIVE MAINTENANCE	788676.	353430.	
PREVENTIVE MAINTENANCE	742032.	742032.	
WARRANTY PRICE		895293.	
AGE	1000000.	734645.	
AGE SUPPORT	470447.	263705.	
TRAINING	350654.	269521.	
DATA	300000.	205230.	
INVENTORY MANAGEMENT	580003.	263926.	
MTBF GUARANTEE		-273988.	
OTHER	50000.	159273.	
TOTAL	18723557.	18009702.	

AVG.MTBFS:	.0 TO 5.0	5.0 TO 10.0	TOTAL
	2546.4	2704.9	2638.4

N INPUT CODE
? 99
READY.

Figure A-7. (continued)

Table A-6. MODEL EQUATIONS	
Equation	Program Line Number
Subassembly MTBF	
$YTF(J) = 1/\sum_{I} NQ(I,J)/XBF(I,J)$	(2760, 2800)
System MTBF	
$SMTBF = 1/\sum_{I}\sum_{J} NQ(I,J)/XBF(I,J)$	(2750, 2990)
Subassembly Mean Time Between Demand (MTBD), Warranty	
$YTD(J) = (1 - FPRW) \times YTF(J)$	(6736)
System MTBD, Organic	
$SMTBDO = (1 - FPRO) \times SMTBF$	(3000)
System MTBD, Warranty	
$SMTBDW = (1 - FPRW) \times SMTBF$	(6224)
System Cost, Organic Maintenance	
$SETQO = \sum_{J} CINSO(J)$	(2780)
System Cost, Warranty	
$SETQW = \sum_{J} CINSW(J)$	(2790)
Total Operating Hours	
$TOH = 12 \times NY \times \sum_{K} [H(K) \times NIB(K)]$	(1610, 1730)
Number of Installed Units	
$NI = \sum_{K} [NIB(K)]$	(1680)
Cumulative Number of Installations	
$NCIY(I) = \sum_{K} NB(K) \times NSCH(I,K)$	(1790, 1830)

(continued)

Table A-6. (continued)

Equation	Program Line Number
<u>Average Operating Hours Per Day</u>	
$HAVG(I) = \sum_K [NIB(K) \times H(K) \times NB(K)/NCIY(K)$	(1650, 1910)
<u>Discount Factors</u>	
$YY_1 = (1 + DR)^{-0.5}$	(3350)
$YY_2 = (1 + DR)^{-1}$	(3370)
Average over (O, NY),	
$DSCTOT = \frac{Y_1}{NY} \times \frac{1-Y_2^{NY}}{1-Y_2}$	(3520)
Average over (O,TW),	
$DSC1 = \frac{Y_1}{TW} \times \frac{1-Y_2^{TW}}{1-Y_2}$	(5980)
At TW,	
$DSCTW = (1 + DR)^{-TW}$	(5950)
Average over (TW, NY)	
$DSC2 = \frac{Y_1}{NY-TW} \times \frac{Y_2^{TW} - Y_2^{NY}}{1 - Y_2}$	(5970)
At TG,	
$DSCTG = (1 + DR)^{-TG}$	(5890)
<u>Calculate False Pull Rates</u>	
<u>Organic</u>	
$FPRO = PSO \times (1. - POSO) \times (RTOKS + PNRTSSO \times TGDSO) + [(1. - PSO) \times (1. - POMO) + PSO \times (1. - POSO) \times (1. - RTOKS - PNRTSSO)] \times (RTOKM + PNRTSMO \times TGDMO)$	(1084)

(continued)

Table A-6. (continued)	
Equation	Program Line Number
<u>Warranty</u>	
FPRW = PSW × (1. − POSW) × (RTOKS + PNRTSSW × TGDSW) + [(1. − PSW) × (1. − POMW) + PSW × (1. − POSW) × (1. − RTOKS − PNRTSSW)] × (RTOKM + PNRTSMW × TGDMW)	(6046)
<u>Organic Corrective Maintenance Frequency Factor</u>	
CMDL(1) = PSO	(3580)
CMDL(2) = (1. − POSO) × PSO	
CMDL(3) = PNRTSSO × CMDL(2)	
CMDM(1) = 1.0 − PSO	
PRTSSO = 1.0 − PNRTSSO − RTOKS	
CMDM(2) = CMDM(1) × (1.0 − POMO) + PSO × (1 − POSO) × PRTSSO	
CMDM(3) = CMDM(2) × PNRTSMO	
<u>Warranty Corrective Maintenance Frequency Factor</u>	
WMDL(1) = PSW	(6010)
WMDL(2) = (1. − POSW) × PSW	
WMDL(3) = PNRTSSW × WMDL(2)	
WMDM(1) = 1.0 − PSW	
PRTSSW = 1.0 − PNRTSSW − RTOKS	
WMDM(2) = WMDM(1) × (1.0 − POMW) + PSW × (1 − POSW) × PRTSSW	
WMDM(3) = WMDM(2) × PNRTSMW	
<u>Modification Factors for MTBF and False Pull Rates as Shown At Base</u>	
BIDSO = (1. − FPRO)/[PSO × (1. − POSO)]	(3670)
BIDSW = (1. − FPRW)/[PSW × (1. − POSW)]	(6080)
BIDMO = (1. − FPRO)/[(1 − POSO) × (1 − POMO) + PSO × (1. − POSO) × (1. − RTOKS − PNRTSSO)]	(3680)

(continued)

Table A-6. (continued)

Equation	Program Line Number
<u>Modification Factors for MTBF and False Pull Rates as Shown At Base (continued)</u>	
BIDMW = (1. - FPRW)/[(1 - POSW) × (1 - POMW) + PSW × (1. - POSW) × (1. - RTOKS - PNRTSSW)]	(6090)
<u>Initialization for Growth Curves</u>	
BW = ALOG (1. + PCTGW)/ALOG (TF/TI)	(6234)
BO = ALOG (1. + PCTGO)/ALOG (TF/TI)	(4000)
TWL = TI × (1. + PLIM) × (1/BW)	(6252)
TOL = TI × (1. + PLIM) × (1/BO)	(4160)
<u>Compute Growth Factors For Each Year of Interest for Organic</u>	
GFO(I) = SF (T1, T2, TI, TOL, BO)	(4250)
<u>Calculate MTBFs for Sparing, Organic</u>	
<u>Module</u>	
PMTB = BIDMO × BF(I,J) × GFO (NGFO)/NQ(I,J)	(4600)
<u>Subassembly</u>	
PMTB = BIDSO × YTF(J) × GFO (NGFO)/NQ(I,J)	(4830)
<u>Total Discard-at-failure Modules, Organic</u>	
NSMDAF(I,J) = TOH × NQ(I,J)/(XBF(I,J) × BIDMO × GFO(NOD)	(4740)
<u>General Spares Equation (Subroutine ISPARE)</u>	
Choose smallest integer S such that $\sum_{k=0}^{S} e^{-X}X^k/k! \geq PSUFF$ where X is the spares demand rate per average pipeline time. If X < 1.5, S = X.	

(continued)

Table A-6. (continued)	
Equation	Program Line Number
<u>Computer Growth Factors for Warranty and Period After Warranty</u>	
GFW(I) = SF(T1, T2, TI, TWL, BW)	(5890)
GFWO(I) = SFWO(T1, T2, TI, TWH, TWL, PLIM, BO, BW)	(6100)
<u>Calculate MTBFs for Sparing, Warranty</u>	
<u>Module</u>	
PMTB = BIDMW × XBF(I,J) × GFW(NGFW)/NQ(I,J)	(6950)
<u>Subassembly</u>	
PMTB = BIDSW × YTF(J) × GFW(NGFW)	(7210)
<u>Total Discard-At-Failure Modules, Warranty</u>	
NWDAF(I,J) = TWH × NQ(I,J)/[XBF(I,J) BIDMW × GFW(NWD)]	(7110)
<u>Calculate MTBFs for Sparing, After Transition</u>	
<u>Module</u>	
PMTB = BIDMO × BF(I,J) × GDWD(NWOD)/NQ(I,J)	(7490)
<u>Subassembly</u>	
PMTB = BIDS × YTF(J) × GDWD(NWOD)	(7660)
<u>Total Discard-At-Failure Modules, After Transition</u>	
NSMA = [NY - TW)/NY] × TOH × NQ(I,J) /[GFWO(NWOD) × XBF(I,J) × BIDMO]	(7980)
<u>Set Acquisition Costs</u>	
Organic Maintenance Initially	
ACO = NI × CINSO(J)	(9170)
Warranty Initially	
ACW = NI × CINSW(J)	(9180)

(continued)

Table A-6. (continued)	
Equation	Program Line Number
Spares Cost	
Organic Maintenance - Subassemblies	
$CSLRU = \sum_{J} [NSLB(J) \times CL(J)] - VXLR$	(5060, 5620)
Organic Maintenance - Repairable Modules	
$CREPM = \sum_{I,J} \left[NRM(I,J) \times C(I,J)\right] - VEM - VUM$	(5500)
Organic Maintenance - DAF Modules	
$CCDAF = \sum_{I,J} \left[NSMDAF(I,J) - NUDAF \times PUDAF\right] \times C(I,J) \times DSCTOT$	(5530)
RIW - Subassemblies	
Cost of Required Subassemblies	
$CSLW = \sum_{J} NAS(J) \times CLW(J)$	(7330)
Value of Excess Complete Subassemblies	
$VXLR = \sum_{J} \left[NSLX(J) - MAX(J)\right] \times CLW(J) \times AMORT$	(8430)
where	
$NSLX(J) = NSLW(J) - NSLBT(J)$	
[For $NSLX(J)<0$, j^{th} - subassembly value = 0]	
Subassembly Net Cost (CSLWN)	
$CSLWN = CSLW - VXLR$	(8910)

(continued)

Table A-6. (continued)

Equation	Program Line Number
Warranty - Repairable Modules	
During Warranty Period	
$\mathrm{CMODW} = \sum_{I,J} \mathrm{NSMW}(I,J) \times C(I,J)$	(7070)
Additional Module Needed After Transition	
$\mathrm{CSMW} = \sum_{I,J} \left[\mathrm{NMW}(I,J) - \mathrm{NSMW}(I,J)\right] \times C(I,J) \times \mathrm{DSCTW}$	(7950)
Required Modules Spares Cost	
$\mathrm{CRMOD} = \mathrm{CMODW} + \mathrm{CSMW}$	(8800)
Value of Excess Repairable Modules	
$\mathrm{VEM}(I,J) = \mathrm{NEM}(I,J) \times \mathrm{VMOD} \times C(I,J)$	(8530, 8600)
Value of Usable Repairable Modules	
$\mathrm{VUM}(I,J) = \begin{cases} \mathrm{NEM}(I,J) \times C(I,J) \times \mathrm{DSCTW}, & \mathrm{NEM}(I,J) > 0 \\ \mathrm{MAX}(J) \times \mathrm{NQ}(I,J) \times C(I,J) \times \mathrm{DSCTW}, & \mathrm{NEM}(I,J) \leq 0 \end{cases}$	(8610) (8640)
Value of Repairable Modules	
$\mathrm{CDEC} = \sum_{I,J} \left[\mathrm{VEM}(I,J) + \mathrm{VUM}(I,J)\right]$	(8660)
Net Cost - Repairable Modules	
$\mathrm{T2NDF} = \mathrm{CRMOD} - \mathrm{CDEC}$	(8920)
RIW - DAF Modules	
Cost of Required DAF Modules During Warranty	
$\mathrm{CWDAF} = \sum_{I,J} \left[\mathrm{NDAF}(I,J) \times C(I,J)\right]$	(7120)

(continued)

Table A-6. (continued)	
Equation	Program Line Number
Spares Cost (continued)	
After Transition	
$CDAF = \sum_{I,J} \left[NSMA(I,J) \times C(I,J) \right] \times DSC2$	(8010)
Value of DAF Modules	
$DDAF = \sum_{I,J} \left[NUDAF(I,J) \times C(I,J) \right] \times PUDAF \times DSC2$	(8720)
Net Cost of DAF Modules	
$CDAF2 = CDAF + CWDAF - DDAF$	(8940)
Total Cost of Required Spares CTOTR	
$CTOTR = CSLW + CRMOD + CDAFT$	(8830)
Total Value of RIW Spares at Transition (TVRS)	
$TVRS = VXLR + CDEC + DDAF$	(8880)
Total Net Cost of RIW Spares	
$TOT2 = TCRS - TVRS$	(8960)
AGE	
Organic Maintenance	
$AGO = AGBO \times NBS + AGDO - (1 - NRT) \times AGBW \times NBS$	(9210)
Warranty/Organic	
$AGWO = AGBW \times NBASE(NTWP1) \times NRT + \left[AGBO \times NBS - AGBW \times NBASE(NTWPI) + AGDO \right] \times DSCTW$	(9220)
Full Warranty	
$AGW = AGBW \times NBS \times NRT$	(9230)

(continued)

Table A-6. (continued)

Equation	Program Line Number
<u>AGE Support</u>	
Organic	
$AGSPO = (AGBO \times NBS \times PAGB + AGDO \times PAGD) \times NY \times DSCTOT$	(9250)
Warranty	
$AGSPW = AGBW \times NBASE(NTWP1) \times TW \times PAGB \times DSC1 + (AGBO \times NBS \times PAGB \times AGDO \times PAGD) \times (NY - TW) \times DSC2$	(9260)
<u>Training</u>	
Organic	
$TRO = \{[WTBO - WTBW \times (1 - NRT)] \times NBS + WTDO\} \times TCPW + (WTBO \times NBS + WTDO) \times TCPW \times NY \times DSCTOT \times RTP$	(9290)
Warranty/Organic	
$TRWO = \{WTBW \times NBASE(NTWP1) + [WTBO \times NBS - WTBW \times NBASE(NTWP1)] \times DSCTW\} \times TCPW + WTDO \times DSCTW \times TCPW + [WTBW \times TW \times NBASE(NTWP1) \times DSC1 + WTBO \times (NY - TW) \times NBS \times DSC2 + WTDO \times (NY - TW) \times DSC2] \times RTP \times TCPW$	(9310, 9330)
Full Warranty	
$TRW = WTBW \times NBS \times TCPW \times (NRT + RTP \times NY \times DSCTOT)$	(9350)
<u>Data</u>	
Organic	
$DATO = DTAO - (1 - NRT) \times DTAW$	(9370)
Warranty/Organic	
$DATWO = DTAW \times NRT + (DTAO - DTAW) \times DSCTW$	(9380)

(continued)

Table A-6. (continued)

Equation	Program Line Number
<u>Data (continued)</u>	
Full Warranty	
$DATW = DTAW \times NRT$	(9390)
<u>Inventory Management</u>	
Organic	
$CIMO = NPCO \times CIM \times NY \times DSCTOT$	(9500)
Warranty	
$CIMW = NPCW \times CIM \times TW \times DSC1 + NPCO \times CIM \times (NY - TW) \times DSC2$	(9510)
<u>Corrective Maintenance Cost</u> (See Subsection 2.3.1 of this appendix for discussion of corrective maintenance algorithm.	
Organic	
$TACMCO = \sum_{K=1}^{n} \left\{ 12 \left[\sum_{I=1}^{2} \sum_{J=1}^{B} AALRCM(I) \times DXO(I,J,K) + Y(K) \times AALRCM(3) \right] \right\}$	(9840)
Warranty	
$TACMCW = \sum_{K=1}^{n} \left\{ 12 \left[\sum_{I=1}^{2} \sum_{J=1}^{B} AALRCM(I) \times DXW(I,J,K) \right] \right\}$	(10080)
Organic After Warranty	
$TACMCWO = \sum_{K=1}^{n} \left\{ 12 \left[\sum_{I=1}^{2} \sum_{J=1}^{B} AALRCM(I) \times DXWO(I,J,K) + Y(K) \times AALRCM(3) \right] \right\}$	(10350)

(continued)

Table A-6. (continued)

Equation	Program Line Number
<u>Preventive Maintenance Cost</u> See Subsection 2.3.3 of this appendix for a description of the preventive maintenance algorithm)	
Organic	
$TAPMCO = 12 \sum_{K=1}^{n} \left\{ \sum_{I=1}^{2} \sum_{L=1}^{B} \left[AALRPM(I) \times Z(I,L,K) \right] + AALRPM(3) \times Z(K) \right\}$	(10590)
Warranty	
$TAPMCW = 12 \sum_{K=1}^{n} \left\{ \sum_{I=1}^{2} \sum_{L=1}^{B} AALRPM(J) \times Z(I,L,K) \right\}$	(10790)
Organic After Warranty	
$TAPMCWO = 12 \sum_{K=1}^{n} \left\{ \sum_{I=1}^{2} \sum_{L=1}^{B} \left[AALRPM(I) \times Z(I,L,K) \right] + AALRPM(3) \times Z(K) \right\}$	(11000)
<u>Consignment Spares (MTBF Guarantee)</u>	
Growth Factor at TG	
$GMG = \left\{ \left(T_1\right)^{-B_W} \cdot \left(T_c\right)^{B_W} \right.$ IF (GMG .GT. 1 + PLIM) GMG = 1 + PLIM	(11790, 11810)
Subassembly Guarantee Value	
$GMTBF(J) = \frac{GSET \times YTP(J)}{SMTBL}$	(11850, 11860)
Factor for Number of Consignment Subassembly Spares	
$X(J) = \frac{GMTBF(J)}{YTP(J) \times GMG} - 1 \quad (0 \leq X(J) \leq 1)$	(11900)

(continued)

Table A-6. (continued)	
Equation	**Program Line Number**
Consignment Spares (MTBF Guarantee) (continued)	
Value of Consignment Spares (Negative Cost)	
$CSGW = -\sum_{J} X(J)\ CLW(J) \times TSP(J) \times NI \times DSCTG$	(11930)
Warranty Price	
$RIW = RDP \times (RIWT + RIWY + RIWTP)$	(11630)
Yearly Cost	
$RIWY = YCOTHW \times TW \times PSCZ$	(11610)
Maintenance, Data, and Administrative Cost	
$RIWT = (RIWCM + RIWPM) \times (1 + DTP)$	(11590)
Corrective Maintenance Cost	
$RIWCM = 12 \sum_{K=1}^{n} \left\{ \sum_{I=1}^{2} \sum_{L=1}^{B} \left[CALRPM(I) \times X(I,L,K) + CALRPM(3) \times Y(I,L,K) \right] \right\}$	(11340)
$RIWPM = 12 \sum_{K=1}^{n} \left\{ \sum_{I=1}^{2} \sum_{L=1}^{B} \left[CALRPM(I) \times Z(I,L,K) + CALRPM(3) \times Y(I,L,K) \right] \right\}$	(11560)
Note: If RSK = 0, RIW = RIWFP	(11070, 11080)
Other Costs	
Organic	
$XOTHO = YOTHO \times NY \times DSCTOT \times OTHO$	(11950)
Warranty/Organic	
$XOTHW = YOTHW \times TW \times DSC1 + YOTHO \times (NY - TW) \times DSC2 + OTHWO + CTRANS \times DSCTW + RIW \times CWP$	(11960)

(continued)

Table A-6. (continued)

Equation	Program Line Number
Other Costs (continued)	
Full Warranty	
XOTHW = YOTHW × NY × DSCTOT + OTHW + RIW × OWF	(11980)
Total Costs	
Organic	
TOTO = ACO + AGO + AGSPO + TRO + DATO + TACMCO + TAPMCO + CSORG + CIMO + XOTHO	(11990)
Warranty/Organic	
TOTWO = ACW + AGWO + AGSPW + TRWO + DATWO + TACM + TAPM + TOT2 + RIW + CIMW + CSGW + XOTHWO	(12040)
Full Warranty	
TOTW = ACW + AGW + AGSPW + TRW + DATW + TACM + TAPM + CSW + RIW + CIMW + CSGW + XOTHW	(12010)
Warranty Savings/Loss	
WSL = TOTO - TOTWO	(12100)

Table A-7. DEFINITION OF COMPUTER PROGRAM AND EQUATION SYMBOLS*	
Symbol	Definition
AALRCM(M)*	Air Force labor rate for corrective maintenance at level M
AALRPM(M)*	Air Force labor rate for preventive maintenance at level M
ACMMLO(M)*	Air Force corrective maintenance man-hours on a subassembly at maintenance level M for organic support
ACMMLW(M)*	Air Force corrective maintenance man-hours on a subassembly at maintenance level M for warranty maintenance
ACMMMO(M)*	Air Force corrective maintenance man-hours on a module at maintenance level M for organic maintenance
ACMMMW(M)*	Air Force corrective maintenance man-hours on a module at maintenance level M for warranty maintenance
ACO	Acquisition cost, organic maintenance
ACW	Acquisition cost, warranty
AFCMHB(M,K)*	Minimum Air Force corrective maintenance man-hours for organizational and intermediate levels for base type K
AFCMHD*	Fixed Air Force corrective maintenance man-hours for depot level
AFPMMD*	Fixed Air Force preventive maintenance man-hours for depot level
AGBO*	Cost of base AGE per base, organic maintenance
AGBW*	Cost of base AGE per base, warranty
AGDO*	Cost of depot AGE, organic maintenance
AGO	Total cost of AGE, organic maintenance
AGSPO	Cost of AGE support, organic maintenance
AGSPW	Cost of AGE support, warranty
AGW	Total cost of AGE, warranty
AGWO	Total cost of AGE, warranty/organic
AMORT	Calculated amortization factor for valuing excess complete subassemblies at transition
BO	Exponential in Duane growth curve for Organic
BMORT*	Adjustment factor to linear depreciation
BW	Exponential in Duane growth curve for Warranty
*Input data are denoted by an asterisk(*).	

(continued)

Table A-7. (continued)	
Symbol	Definition
C(I,J)*	Cost of i^{th} module in j^{th} subassembly
CCDAF	Cost of discard-at-failure module requirement over equipment life, organic maintenance
CCMML(M)	Contractor corrective maintenance man-hours for subassemblies at the maintenance level M
CDAF2	Net cost of discard-at-failure modules, warranty
CCMMM(M)	Contractor corrective maintenance man-hours for modules at the maintenance level M
CFCMHD*	Minimum man-hours for corrective maintenance at the depot for the contractor
CFPMMD*	Minimum man-hours for preventive maintenance at the depot for the contractor
CIM*	Cost per year for inventory management of a unique item
CIMO	Total inventory management cost, organic maintenance
CIMW	Total inventory management cost, warranty
CINSO(J)*	Acquisition cost of installed j^{th} type subassembly, organic maintenance
CINSW(J)*	Acquisition cost of installed j^{th} type subassembly, warranty
CL(J)*	Acquisition cost for a spare j^{th} subassembly, organic maintenance
CLW(J)*	Acquisition cost for a spare j^{th} subassembly, warranty
CREPM	Cost of repairable module spares requirement, organic maintenance
CSGW	Value of consignment spares for MTBF guarantee
CSLRU	Cost of required spare subassemblies, organic maintenance
CSLW	Cost of required spare subassemblies, warranty
CSORG	Total spares costs (repairable and discard-at-failure items), organic maintenance
CSW	Total spares costs (repairable and discard-at-failure items), full warranty
CTRANS*	Other costs for transition from warranty to organic maintenance
DATO	Total data cost, organic maintenance
DATW	Total data cost, full warranty

(continued)

Table A-7. (continued)	
Symbol	Definition
DATWO	Total data cost, warranty/organic
DR*	Discount rate
DSC1	Average discount rate over (O, TW)
DSC2	Average discount rate over (TW, NY)
DSCTG	Discount rate at T_G
DSCTOT	Average discount rate over (O, NY)
DSCTW	Discount rate at TW
DTAO*	Data cost, organic maintenance
DTAW*	Data cost, warranty
DTP*	Data and administration cost factor for warranty pricing
FO	Factor for organic raliability growth
FOFW	Factor for warranty reliability growth over (TW, NY)
FPRO	False-pull rate for organic
FPRW	False-pull rate for warranty
FW	Factor for warranty reliability growth over (O, TW)
FWO	Factor for warranty reliability growth over (O, NY)
GFO(I)	Growth factor for organic maintenance in year I
GFW(I)	Growth factor for warranty maintenance in year I
GFWO(I)	Growth factor for period after transition for year I
GMG	Factor for reliability growth applicable at time TG
GMTBF	Allocated unit guaranteed MTBF value (j^{th} subassembly)
GOFW	Average growth MTBF over (TW, NY), warranty
GORG	Average growth MTBF over (O, NY), organic maintenance
GSET*	Equipment guaranteed MTBF value
H(K)	Average operating hours per day for base type K
HM(K)	Average operating hours per month for base type K
I	Index -- generally used to represent the i^{th} module
J	Index -- generally used to represent the j^{th} subassembly
K	Index -- generally used to represent base type K
MAX(J)	The number of excess subassemblies of the j^{th} type to be disassembled at transition for obtaining necessary modules

(continued)

Table A-7. (continued)	
Symbol	Definition
NB(K)	Number of installations per base at base type K
NBS	Total number of bases
NBX	Number of types of bases
NBY(K)	Number of years over which delivery schedule is spread for base type K
NCIB(I, K)	Cumulative number of installed bases in year I for base type K
NCIY(I)	Cumulative number of installations for year I of all bases
NEM(I,J)	Number of excess modules of type (i, j) at transition
NI	Total number of installations
NIB(K)	Total number of installations for base type K
NIY(I)	Number of installations for year I for all bases
NMW(I,J)	Total number of required spare modules at the bases for the i^{th} module type in the j^{th} subassembly at transition
NPCO*	Number of unique P-coded items, organic maintenance
NPCW*	Number of unique P-coded items, warranty
NQ(I,J)*	Number of modules for i^{th} module type in j^{th} subassembly
NRM(I,J)	Total spares requirement for repairable (i,j) module at transition
NSCH(I,K)	Incremental schedule of installed bases by year I for each base type K
NSLB(J)	Total spares requirement for j^{th} subassembly, organic maintenance
NSLBT(J)	Required subassembly spares after transition
NSLW(J)	Required subassembly spares during warranty
NSMA	Total number of discard-at-failure events following warranty
NSMDAF(I,J)	Total discard-at-failure events for i^{th} module, j^{th} subassembly -- organic maintenance
NSMW(I,J)	Required module spares during warranty
NUDAF(I,J)	Number of usable DAF type (i,j) modules at transition
NWC	Flag to designate type of warranty concept
NWDAF(I,J)	Total discard at failure events for i^{th} module, j^{th} subassembly -- warranty
NY*	Number of life-cycle years under consideration

(continued)

Table A-7. (continued)

Symbol	Definition
OTHO*	"Other" fixed government costs, organic maintenance
OTHW*	"Other" fixed government costs, full warranty
OTHWO*	"Other" fixed government costs, warranty/organic
OWF*	Factor for computing costs for noncovered failures under warranty
PAGB*	Factor for base AGE support
PAGD*	Factor for depot AGE support
PCTGO*	Percentage of MTBF growth from 1,000 to 50,000 operating hours for organic maintenance
PCTGW*	Percentage of MTBF growth from 1,000 to 10,000 operating hours for warranty
PFT*	Contract profit factor, warranty
PLIM*	Upper growth limit of MTBF expressed in percentage of initial MTBF
PMRO(M)*	Preventive maintenance rate at each level of maintenance for organic
PMRW(M)*	Preventive maintenance rate at each level of maintenance for warranty
PNRTSMO*	Probability of Not-Repairable-This-Station for a module under organic maintenance at the intermediate level
PNRTSMW*	Probability of Not-Repairable-This-Station at the intermediate level for a module under warranty maintenance
PNRTSSO*	Probability of Not-Repairable-This-Station for a subassembly under organic maintenance at the intermediate level
PNRTSSW*	Probability of Not-Repairable-This-Station at the intermediate level for a module under warranty maintenance
POMO*	Probability of repairing a module at the organizational level under organic maintenance
POMW*	Probability of repairing a module at the organizational level under warranty maintenance
POSO*	Probability of repairing a subassembly at the organizational level under organic maintenance
POSW*	Probability of repairing a subassembly at the organizational level under warranty maintenance

(continued)

Table A-7. (continued)

Symbol	Definition
PSO*	Probability that a maintenance action at the organizational level is for a subassembly under organic maintenance
PSW*	Probability that a maintenance action at the organizational level is for a subassembly under warranty maintenance
PSUFF*	Spares-sufficiency probability
PUDAF*	Percentage of DAF modules available at transition that will be used
RIW	Total warranty price
RSK*	Contractor risk factor for warranty pricing
RTOKS*	The probability that a subassembly will Retest OK at the intermediate level; this applies for organic and warranty
RTOKM*	The probability that a module will Retest OK at the intermediate level; this applies for organic and warranty
RTP*	Factor for calculating recurring training costs
SETQO	System cost, organic maintenance
SETQW	System cost, warranty
SF	Function for computing MTBF growth for full [illegible] warranty
SFLC	Function for computing MTBF growth for entire [illegible]
SFWO	Function for computing MTBF growth for organic after warranty
SMTBDO	Initial system MTBD, organic
SMTBDW	Initial system MTBD, warranty
SMTBF	Initial system MTBF
TBRCO*	Base-cycle-repair time under organic maintenance
TBRCW*	Base-cycle-repair time under warranty maintenance
TCPW*	Training cost per man-week
TDRCMO*	Depot-repair-cycle time for modules under organic maintenance
TDRCMW*	Depot-repair-cycle time for modules under warranty maintenance
TDRCSO*	Depot-repair-cycle time for subassemblies under organic maintenance
TDRCSW*	Depot-repair-cycle time for subassemblies under warranty maintenance

(continued)

Table A-7. (continued)	
Symbol	Definition
TG*	Years of operation associated with a guaranteed MTBF value
TGDMO*	Probability that a module will test "good" at the depot, organic
TGDMW*	Probability that a module will test "good" at the depot, warranty
TGDSO*	Probability that a subassembly will test "good" at the depot, organic
TGDSW*	Probability that a subassembly will test "good" at the depot, warranty
TOH*	Total operating hours over life cycle
TOSM*	Order and ship time for a module from base to depot
TOSS*	Order and ship time for a subassembly from base to depot
TOT2	Total spares cost (repairable and discard-at-failure items), warranty/organic
TRO	Training costs, organic maintenance
TRW	Training costs, full warranty
TRWO	Training costs, warranty/organic maintenance
TSP(J)*	Target spares *percentage factor* for j^{th} LRU MTBF guarantee
T2NDF	Net cost of spare repairable modules, warranty
TW*	Warranty period in years
VEM(I,J)	Total value of excess modules of type ij at transition
VUM(I,J)	Total value of usable modules of type ij at transition
WP	Ratio of warranty period to life-cycle period
WPPD	Discounted yearly warranty price as percentage of acquisition cost of installed set
WSL	Warranty savings or loss
WTBO*	Man-weeks of training for base maintenance, organic
WTBW*	Man-weeks of training for base maintenance, warranty
WTDO*	Man-weeks of training for depot maintenance, organic
XBF(I,J)*	Initial MTBF of i^{th} module in j^{th} subassembly
XOTHO	Total "other" costs, organic maintenance
XOTHW	Total "other" costs, full warranty
XOTHWO	Total "other" costs, warranty/organic

(continued)

Table A-7. (continued)	
Symbol	Definition
XY	Number of life-cycle years under consideration (same as NY)
YCOTHW*	Yearly other contractor costs, warranty
YOTHO*	Yearly "other" government costs, organic maintenance
YOTHW*	Yearly "other" government costs, warranty
YTD(J)	Mean time between demands for jth subassembly, warranty
YTF(J)	Mean time between failures for j^{th} subassembly

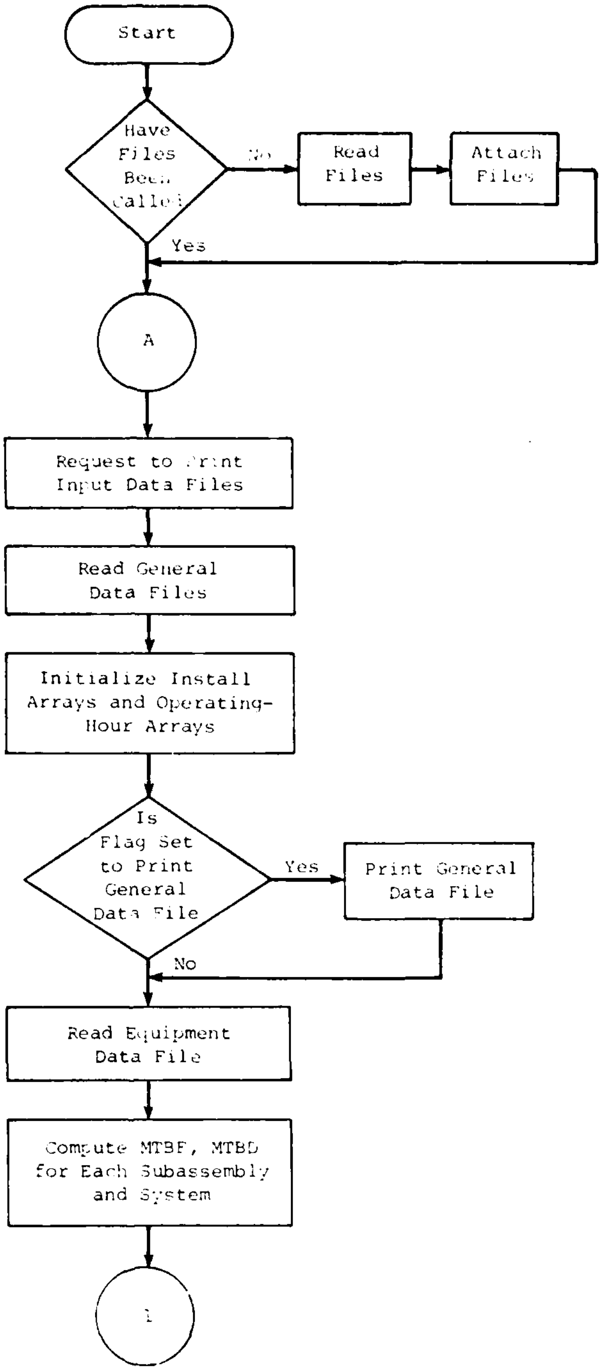

Figure A-8. FLOW DIAGRAM FOR LCC WARRANTY VERSUS ORGANIC MAINTENANCE

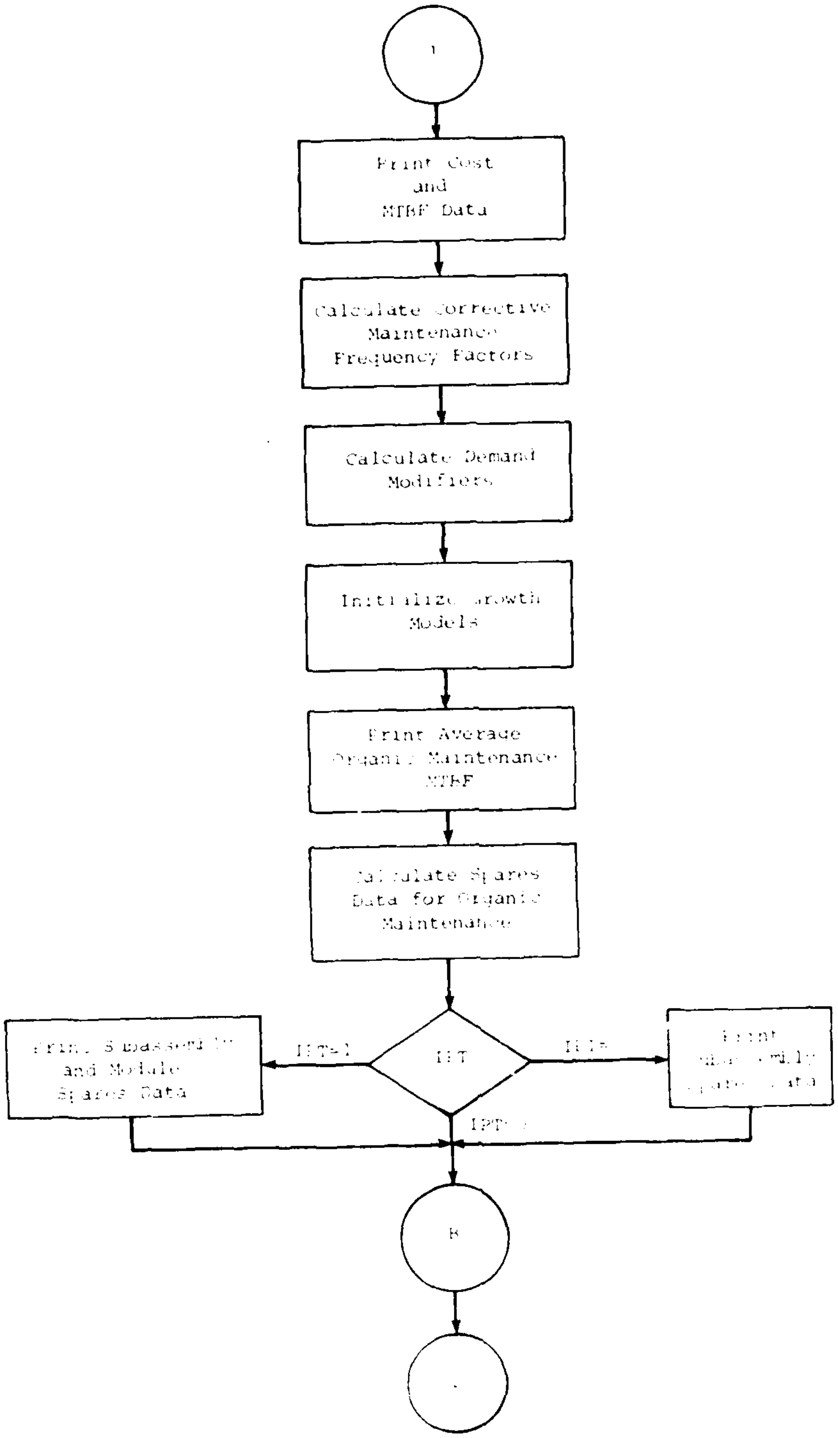

Figure A-8. (continued)

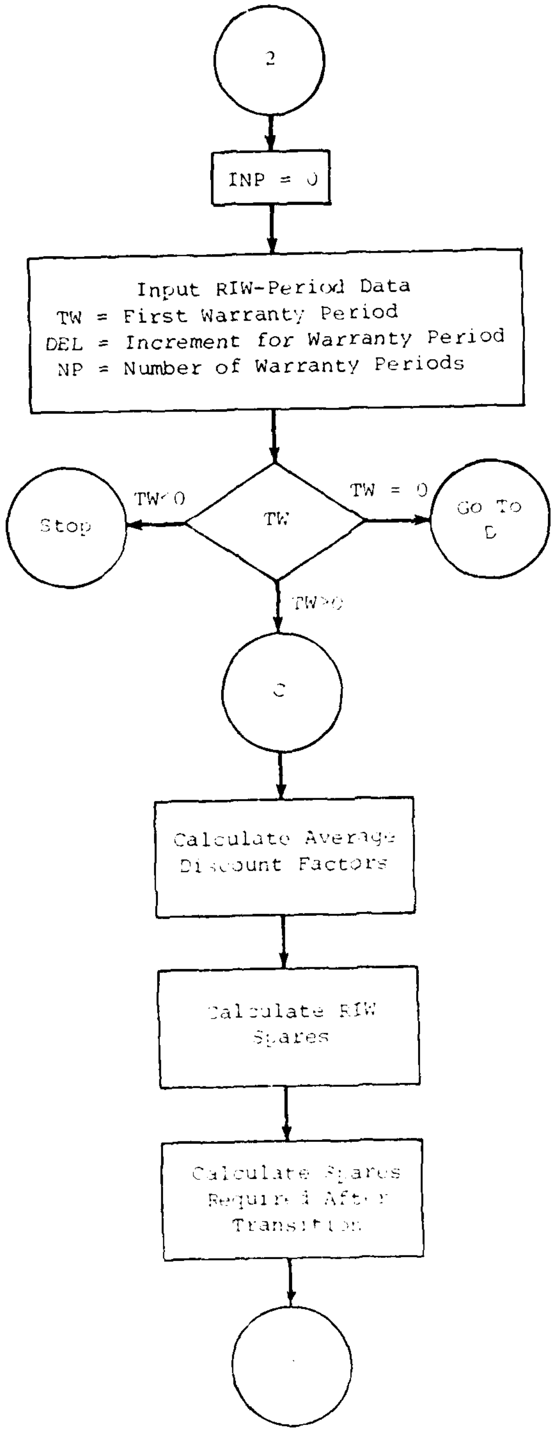

Figure A-8. (continued)

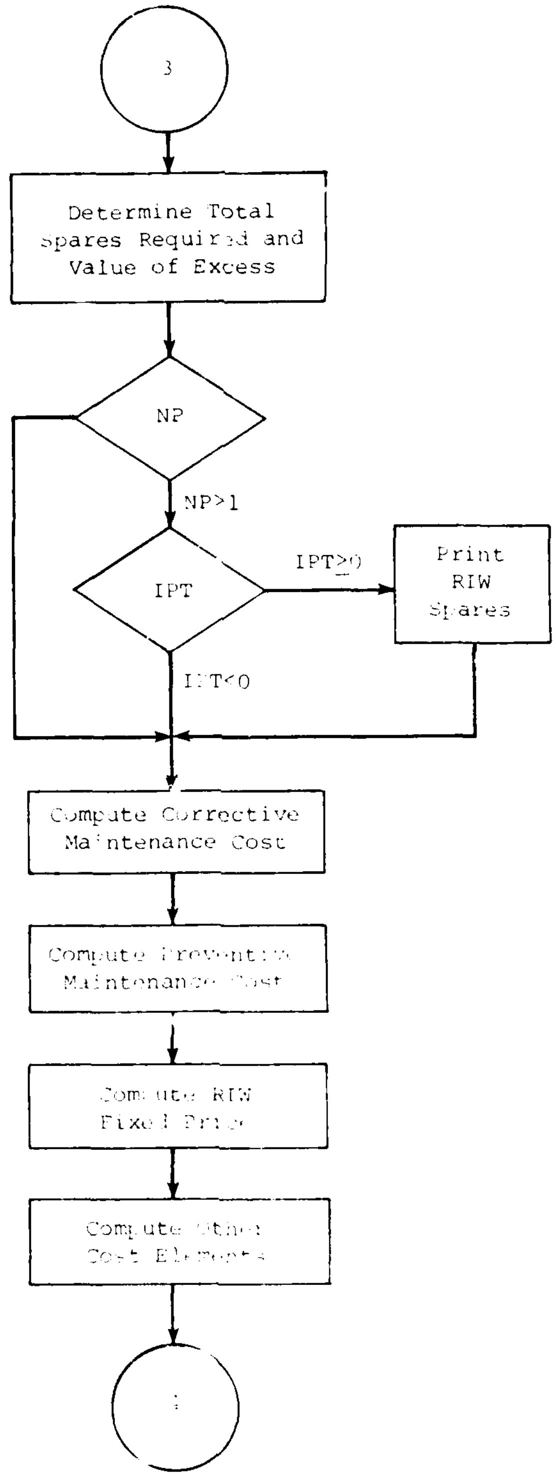

Figure A-8. (continued)

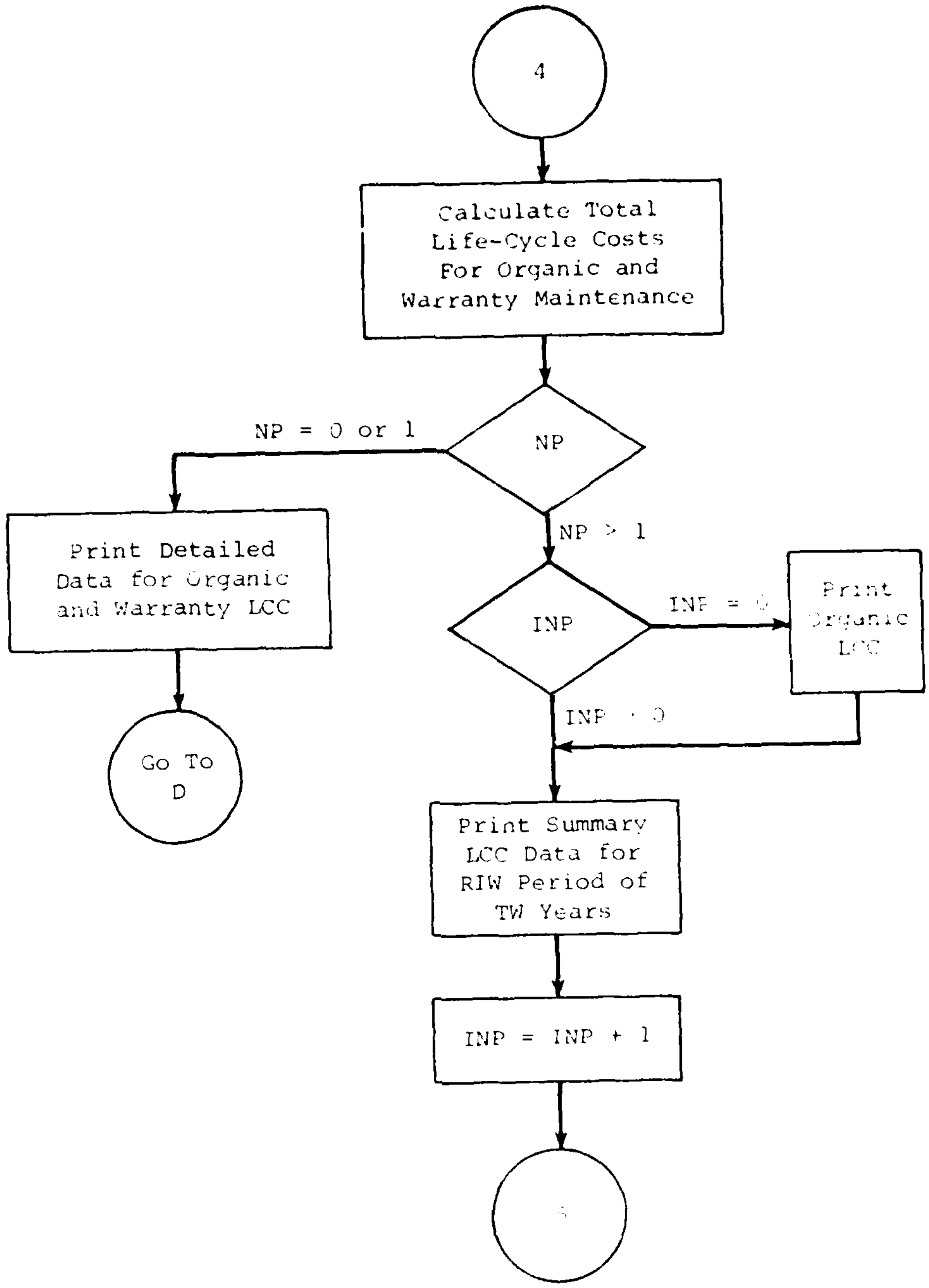

Figure A-8 (continued)

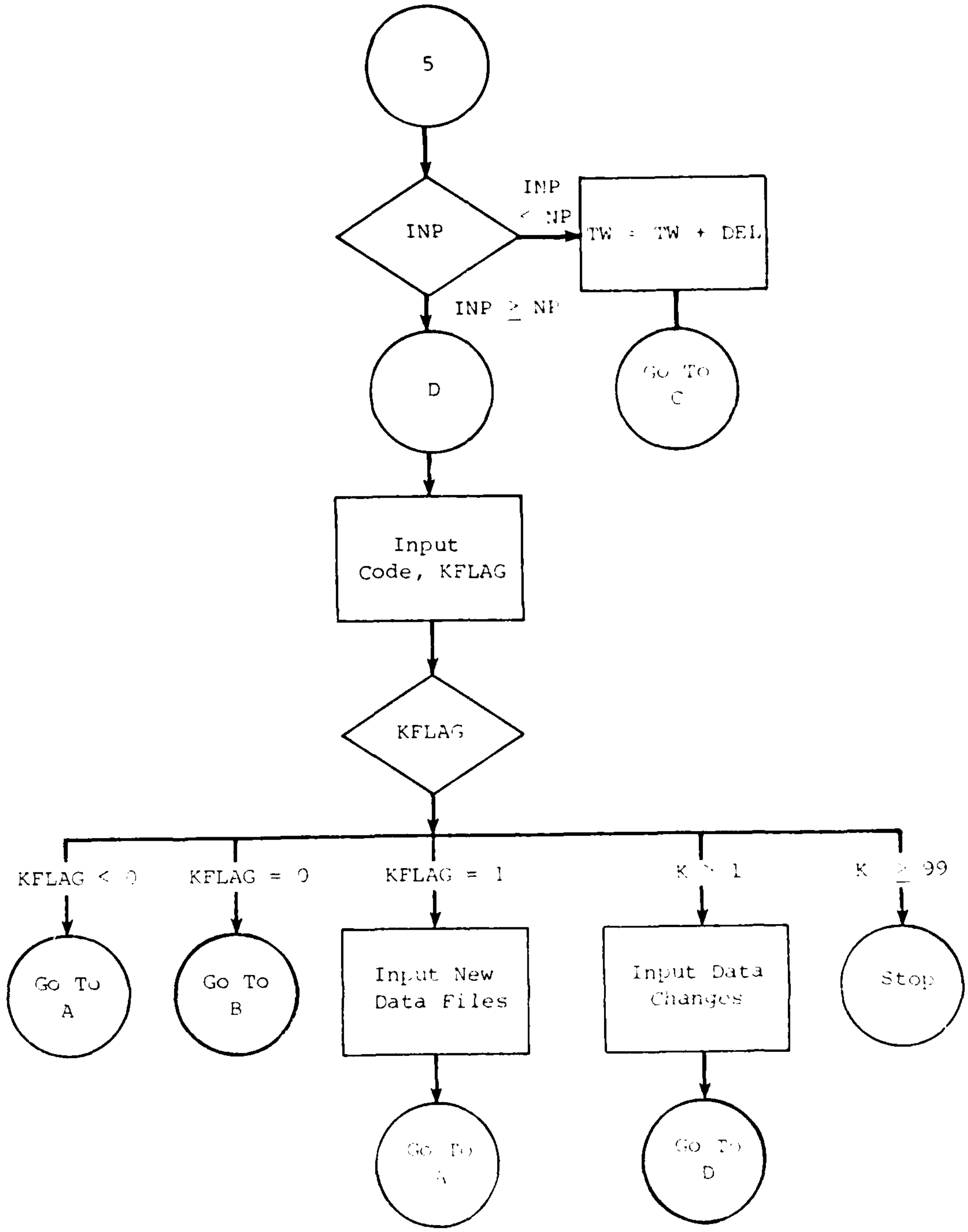

Figure A-8. (continued)

```
LIST

 79 09 05. 16.36.31.
PROGRAM   WGLCC

PROGRAM RADC (INPUT,OUTPUT,TAPE1,TAPE2)
INTEGER NSCH(21,5),NCIY(21),NIY(21),
+          NO(5),NW(5),NWD(5),NPASE(21)
C
REAL NPTS,NCIB(21,5)
REAL DPHYB(21,5),DPHY(21),HAVG(21),GFO(21),GFW(21),GFWO(21)
REAL NSMA
DIMENSION YTF(10),CL(10),NMOD(10),NO(55,10)
+ ,XBF(55,10),C(55,10),IDF(55,10),ERRMSG(5)
+ ,CLW(10),CINSO(10),CINSW(10)
+ ,NSLB(10),NSMB(55,10),CLB(10)
+ ,NSMDAF(55,10),H(5),NIB(5),NB(5),NWD(5)
+ ,NSLW(10),NSLX(10)
+ , YTD(10),TSP(10),NMW(55,10)
+ ,MAX(10),NPM(55,10),NSMX(55,10)
+  ,NSLBT(10),NLBSL(5)
+ ,IMOD(55,10),LM1(10),LM2(10)
DIMENSION CFCMHB(2,5),AFCMHB(2,5),CALFCM(3),AALFCM(3),CMDL(3),CMDM(3),
+ CCMML(3),ACMMLO(3),ACMMLW(2),CCMMM(3),ACMMMO(3),ACMMMW(2),CFRMMB(2,5),
+  AFRMMB(2,5),CALFRM(3),AALFRM(3),RMRO(3),RMRW(3),ACMHMW(2,5),
+  ACMHMO(2,5),DXO(2,5),DXW(2,5),DXWO(2,5),DISC(21),
+  ACMHMWO(2,5),CINH(21),TINCWO(10,5),NWDAF(55,10)
+ ,WMDL(3),WMDM(3),TINCO(10,5),TINCW(10,5),FXBF(55,10),NSMW(55,10)
DIMENSION HM(5),LS(5),NRY(5),LCM(5),LRM(5),LSY(5,21)
DATA DPHYB/105*0.0/,DPHY/21*0.0/,HAVG/21*0.0/
DATA GFO/21*0.0/,GFW/21*0.0/,GFWO/21*0.0/
DATA NSCH/105*0/,NCIB/105*0/,NCIY/21*0/
DATA NIY/21*0/,NO/5*0/,NW/5*0/,NWD/5*0/
C
C  DEFINE FUNCTION TO COMPUTE AVERAGE DISCOUNT OVER INTERVAL (YS,YF)
DAVG(YS,YF) = YY1*(YY2**YS-YY2**YF)/((YF-YS)*(1.-YY2))
YFACM = 1.0
C
NPT = 1
KFLAG = 0
PRINT *,"       WARRANTY LCC ANALYSIS"
PRINT *," FILES CALLED? 0 FOR NO, 1 FOR YES"
READ *,IFL
IF(IFL.EQ.0) GO TO 8030
45 CONTINUE
C
C PRINT *,"INPUT 1 FOR INITIAL WRNTY ANALYSIS;ELSE 0"
C READ *,NPT
NPT = 1
50 CONTINUE
C
PRINT *," DO YOU WANT GENERAL DATA FILE PRINTED, 1-YES, 0-NO"
READ *,IGEN
PRINT *," DO YOU WANT EQUIPMENT DATA FILE PRINTED, 1-YES, 0-NO"
READ *,IEQP
IF(KFLAG .LT. 0) GO TO 855
REWIND 1
READ(1,*) L1,PNPTSSO,PNPTSSW,PNPTSMO,PNPTSMW
READ(1,*) L2,RSO,RSW,RTOKS,RTOKM
READ(1,*) L3,ROSO,ROSW,ROMO,ROMW
READ(1,*) L33,TGDSO,TGDSW,TGDMO,TGDMW
READ(1,*)  L4,TBRCO,TBRCW,TOSS,TOSM
```

(continued)

Figure A-9. PROGRAM LISTING

```
00660 READ(1,*) L5,TDRCSD,TDRCSW,TDRCMD,TDRCMW
00670 READ(1,*) L6,RMORT,VMOD,RUDAF
00680 READ(1,*) L7,RSUFF,NS,DR,NMC
00690 READ(1,*) L8,CFCMHD,AFCMHD
00700 READ(1,*) L9,(CALRCM(IJ),IJ=1,3)
00710 READ(1,*) L10,(AALRCM(IJ),IJ=1,3)
00720 READ(1,*) L11,(CCMML(IJ),IJ=1,3)
00730 READ(1,*) L12,(ACMMLD(IJ),IJ=1,3)
00740 READ(1,*) L13,(ACMMLW(IJ),IJ=1,2)
00750 READ(1,*) L14,(CCMMM(IJ),IJ=1,3)
00760 READ(1,*) L15,(ACMMMD(IJ),IJ=1,3)
00770 READ(1,*) L16,(ACMMMW(IJ),IJ=1,2)
00780 READ(1,*) L17,CFRMMD,AFRMMD
00790 READ(1,*) L18,(CALRRM(IJ),IJ=1,3)
00800 READ(1,*) L19,(AALRRM(IJ),IJ=1,3)
00810 READ(1,*) L20,(RMRD(IJ),IJ=1,3)
00820 READ(1,*) L21,(RMRW(IJ),IJ=1,3)
00830 READ(1,*) L22,AGBD,AGBW,AGDD,RAGB,RAGD
00840 READ(1,*) L23,TCRW,WTBD,WTDD,WTBW,RTR
00850 READ(1,*) L24,DTAD,DTAW
00860 READ(1,*) L25,RSK,RRT,DWF,DTR,RIWRR,YCDTHW
00870 READ(1,*) L26,NRCD,NRCW,CIM
00880 READ(1,*) L27,OTHD,OTHW,OTHWD,YOTHD,YOTHW,CTRANS
00890 READ(1,*) L28,SSET,TG
00900 READ(1,*) L29,PCTGW,PCTGD,PLIM,NRX
00910 955 CONTINUE
00920C  DETERMINE LEVEL OF REPAIR FOR MAINTENANCE CONCEPT AND SET FLAGS
00930 NRTSSD = RNRTSSD+ RTOKS + .0001
00940C  SET FLAG FOR TYPE OF SUBASSEMBLY SPARING
00950 JSPRD = 2
00960 IF(NRTSSD .EQ. 1) JSPRD=1
00970C
00980C  CHECK FOR NRTS + RTOK .GT. 1
00990 JCH = RNRTSSD + RTOKS - .0001
01000 IF(JCH .LT. 1) GO TO 958
01010 RNRTSSD = 1.0 - RTOKS
01020 PRINT *,"NRTS SET TOO HIGH FOR SUBASSEMBLIES,ORGANIC"
01030 958 CONTINUE
01040 JCH = RNRTSMD + RTOKM - .0001
01050 IF(JCH .LT. 1) GO TO 968
01060 RNRTSMD = 1.0 - RTOKM
01070 PRINT *,"NRTS SET TOO HIGH FOR MODULES,ORGANIC"
01080 968 CONTINUE
01082C  COMPUTE FALSE PULL RATES
01084 FPRD = RSD*(1.-RDSD)*(RTOKS + RNRTSSD*TGDSD) +
01086+        ((1.-RSD)*(1.-RDMD)+RSD*(1.-RDSD)*(1.-RTOKS-RNRTSSD))
01088+      *(RTOKM + RNRTSMD*TGDMD)
01090 IF(KFLAG .LT. 0) GO TO 1720
01130 TOH = 0.0
01140 NBS = NT = 0
01142 OFHS(1) = 0.0
1143 DO 1145 IJ=1,21
1144 NBASE(IJ) = 0
1145 1145 CONTINUE
01150C READ IN SCHEDULE OF INSTALLS
01160C SETUP LOOP ON TYPES OF BASES
01170 DO 10700 LBT=1,NB
01180C  READ # OF SYSTEMS PER BASE,OP HR/MO,# OF YEARS OVER WHICH THE SCHEDULE
01190C  IS SPREAD,# OF BASES WITH FULL INSTALLS AT START OF PROGRAM.
01200 READ(1,*) LS(LBT),NB(LBT),HM(LBT),NBY(LBT),NSCH(1,LBT)
01210 OPTCN = HM(LBT)*12.
01220C  SET UP DO LOOP TO READ IN SCHEDULE FOR EACH BASE TYPE
```

(continued)

Figure A-9. (continued)

```
01230 LBIT = NBY(LBT)
01240 LMOD = LBIT/5
01250 LREM = MOD(LBIT,5)
01260 REM = LREM
01270 REM = .1*REM + .01
01280 LREM = REM
01290 LBSL = LMOD + LREM
01300 NLBSL(LBT) = LBSL
01310C CONVERT OP HR/MO TO OP HR/DAY
01320 H(LBT) = HM(LBT)/30.5
01330C  LOOP TO READ SCHEDULE FOR EACH BASE TYPE
01340 IF(LBIT .EQ. 0) GO TO 10655
01350 DO 10650 LBS=1,LBSL
01360 LBSI = (LBS-1)*5 + 2
01370 LBSF = LBSI + 4
01380C  READ # BASES WITH FULL INSTALLS FOR EACH YEAR FOR FIVE CONSECUTIVE
01390C  YEARS
01400 READ(1,*) LSY(LBT,LBS),(NSCH(II,LBT),II=LBSI,LBSF)
01410 10650 CONTINUE
01420 10655 CONTINUE
01430 FNSCH = NSCH(1,LBT)
01440 NCIB(1,LBT) = NSCH(1,LBT)
01480C  ACCUMULATE # OF INSTALLS PER BASE TYPE
01490 NIB(LBT) = NB(LBT)*NSCH(1,LBT)
01512 NYP1 = NY + 1
1514 NBASE(1) = NBASE(1) + NCIB(1,LBT) + .01
01520 DO 10680 II=2,NYP1
01530 IIM1 = II - 1
01532 IIM2 = II - 2
01540C  ACCUMULATE OP HRS PER YEAR PER BASE
01550 FNSCH = NSCH(II,LBT)
01560C CALCULATE CUMULATIVE # OF INSTALLED BASES PER YEAR PER BASE TYPE
01570 NCIB(II,LBT) = NCIB(IIM1,LBT) + NSCH(II,LBT)
01580 FNCIB = NB(LBT)*(NCIB(II,LBT) + NCIB(IIM1,LBT))
01582 FNCIB = FNCIB*.5
01584 IF(II .GT. 2) GO TO 10678
01586 OPHYB(1,LBT) = OPCON*FNCIB
01588 GO TO 10679
01589 10678 CONTINUE
01590 OPHYB(IIM1,LBT) = OPCON*FNCIB + OPHYB(IIM2,LBT)
01600C  ACCUMULATE OP HRS PER YEAR
01602 10679 CONTINUE
01610 OPHY(IIM1) = OPHY(IIM1) + OPHYB(IIM1,LBT)
01620C  ACCUMULATE # OF INSTALLS PER BASE TYPE
01630 NIB(LBT) = NB(LBT)*NSCH(II,LBT) + NIB(LBT)
01640C  1ST PART OF FINDING WEIGHTED AVERAGE OPERATING HOURS/DAY
01650 HAVG(IIM1) = HAVG(IIM1) + FNCIB*H(LBT)
01652C  ACCUMULATE TOTAL # OF BASES
01654 NBASE(II) = NBASE(II) + NCIB(II,LBT) + .01
01660 10680 CONTINUE
01670C  ACCUMULATE TOTAL # OF INSTALLS
01680 NI = NI + NIB(LBT)
01710 10700 CONTINUE
01720 NBS = NBASE(NYP1)
01730 TOH = OPHY(NY)
01740C  COMPUTE ACCUMULATED # OF INSTALLS PER YEAR FOR ALL BASES
01750C
01760 DO 10760 II=1,NYP1
01770 NIY(II) = 0
01780 DO 10750 LBT=1,NBS
01790 NIY(II) = NIY(II) + NB(LBT)*NSCH(II,LBT)
01800 10750 CONTINUE
```

(continued)

Figure A-9. (continued)

```
C  COMPUTE THE CUMULATIVE # OF INSTALLS PER YEAR
IF(II .EQ. 1) GO TO 10755
 NCIY(II) = NCIY(II-1) + NIY(II)
GO TO 10760
10755 NCIY(II) = NIY(II)
10760 CONTINUE
NCIY(1) = NIY(1)
C  COMPLETE CALCULATION OF WEIGHTED AVERAGE OF HRS DAY
DO 10795 II=1,NY
IIP1 = II + 1
PNCIY = NCIY(IIP1) + NCIY(II)
PNCIY = PNCIY*.5
HAVG(II) = HAVG(II) PNCIY
10795 CONTINUE
C  READ IN FIXED CORRECTIVE MAINTANANCE MANHOURS PER BASE PER MONTH
C  FOR SUBASSEMBLIES & MODULES
DO 1420 II=1,NBX
READ(1,*) LCM(II),CFCMHB(1,II),CFCMHB(2,II),AFCMHB(1,II),AFCMHB(2,II)
1420 CONTINUE
C  READ IN FIXED PREVENTIVE MAINTANCE MANHOURS PER BASE TYPE PER
C  MONTH FOR SUBASSEMBLIES & MODULES
DO 1428 II=1,NBX
READ(1,*) LPM(II),CFPMMB(1,II),CFPMMB(2,II),AFPMMB(1,II),AFPMMB(2,II)
1428 CONTINUE
1720 CONTINUE
C   PRINT GENERAL DATA FILE
IF(IGEN .EQ.0) GO TO 1794
PRINT *,"  *GENERAL DATA FILE*"
PRINT 1801, L1,PNRTSID,PNRTSIW,PNRTSMD,PNRTSMW
PRINT 1801, L2,PID,PIW,PTOKS,PTOKM
PRINT 1801, L3,POSD,POSW,POMD,POMW
PRINT 1801, L03,TGDSD,TGDSW,TGDMD,TGDMW
PRINT 1802, L4,TBRCD,TBRCW,TOSS,TOSM
PRINT 1802, L5,TDRCSD,TDRCSW,TDRCMD,TDRCMW
PRINT 1801, L6,BMORT,VMOD,PUDAF
PRINT 1803, L7,PSUFF,NY,DR,NWC
PRINT 1800, L8,CFCMHD,AFCMHD
PRINT 1802, L9,(CALRCM(IJ),IJ=1,3)
PRINT 1802, L10,(AALRCM(IJ),IJ=1,3)
PRINT 1801, L11,(CCMML(IJ),IJ=1,3)
PRINT 1801, L12,(ACMMLD(IJ),IJ=1,3)
PRINT 1801, L13,(ACMMLW(IJ),IJ=1,2)
PRINT 1801, L14,(CCMMM(IJ),IJ=1,3)
PRINT 1801, L15,(ACMMMD(IJ),IJ=1,3)
PRINT 1801, L16,(ACMMMW(IJ),IJ=1,2)
PRINT 1800, L17,CFPMMD,AFPMMD
PRINT 1802, L18,(CALRPM(IJ),IJ=1,3)
PRINT 1802, L19,(AALRPM(IJ),IJ=1,3)
PRINT 1801, L20,(PMRD(IJ),IJ=1,3)
PRINT 1801, L21,(PMRW(IJ),IJ=1,3)
PRINT 1804, L22,AGBD,AGBW,AGDD,PAGB,PAGD
PRINT 1801, L23,TCPW,WTBD,WTDD,WTBW,RTP
PRINT 1800, L24,DTAD,DTAW
PRINT 1805, L25,RIK,PFT,DWF,DTR,RIWFP,YCOTHW
PRINT 1806, L26,NPCD,NPCW,CIM
PRINT 1800, L27,DTHD,DTHW,DTHWD,YOTHD,YOTHW,CTRANS
PRINT 1800, L28,SIET,TG
PRINT 1807, L29,PCTGW,PCTGD,PLIM,NBX
DO 1778 K=1,NBX
PRINT 1808, LI(K),NB(K),HM(K),NBY(K),NICH(1,K)
LBIL = ALBIL(K)
DO 1776 JJ=1,LBIL
```

(continued)

Figure A-9. (continued)

```
LBSI = (JJ-1)*5 + 2
LBSF = LBSI + 4
PRINT 1809, LIY(K,JJ),(NICH(IJ,K),IJ=LBSI,LBSF)
1776 CONTINUE
1778 CONTINUE
DO 1784 K=1,NEX
PRINT 1800,LCM(K),CFCMHB(1,K),CFCMHB(2,K),AFCMHB(1,K),AFCMHB(2,K)
1784 CONTINUE
DO 1792 K=1,NEX
PRINT 1800, LPM(K),CFPMMB(1,K),CFPMMB(2,K),AFPMMB(1,K),AFPMMB(2,K)
1792 CONTINUE
1794 CONTINUE
IF(KFLAG .LT. 0) GO TO 1932
1800 FORMAT( I5,6F10.0)
1801 FORMAT( I5,6F10.4)
1802 FORMAT( I5,6F10.2)
1803 FORMAT( I5,2(F10.5,I10))
1804 FORMAT( I5,3F10.0,2F10.5)
1805 FORMAT( I5,4F10.5,2F10.0)
1806 FORMAT( I5,2I10,F10.0)
1807 FORMAT( I5,3F10.5,2I10)
1808 FORMAT( I5,I10,F10.2,2I10)
1809 FORMAT( I5,5I10)
ICOST=CETOO=CETOW=C=0.
REWIND 2
READ(2,*) LU,NLRU
DO 230 J=1,NLRU
YTF(J)=CL(J)=0.
READ(2,*) LM1(J),NMOD(J),CL(J),CLW(J),TIP(J)
READ(2,*) LM2(J),CINIO(J),CINIW(J)
NM = NMOD(J)
150 DO 210 I=1,NM
READ(2,*) IMOD(I,J),NO(I,J),XBF(I,J),IDF(I,J),C(I,J)
169 CONTINUE
C=C+NO(I,J)*XBF(I,J)
YTF(J)=YTF(J)+NO(I,J)/XBF(I,J)
210 CONTINUE
CETOO=CETOO+CINIO(J)
CETOW=CETOW+CINIW(J)
YTF(J)=1./YTF(J)
230 CONTINUE
1932 CONTINUE
IF(IEOF .EQ. 0) GO TO 1960
PRINT *," "
PRINT *,"  *EQUIPMENT DATA*"
PRINT 1808,LU,NLRU
DO 1955 J=1,NLRU
PRINT 1970, LM1(J),NMOD(J),CL(J),CLW(J),TIP(J)
PRINT 1800, LM2(J),CINIO(J),CINIW(J)
NM = NMOD(J)
DO 1950 II=1,NM
PRINT 1972, IMOD(II,J),NO(II,J),XBF(II,J),IDF(II,J),C(II,J)
1950 CONTINUE
1955 CONTINUE
1960 CONTINUE
1970 FORMAT(I5,I10,2F10.0,F10.5)
1972 FORMAT(I5, 3(I10,F10.0))
IF(KFLAG .LT. 0) GO TO 245
CMTBF=1./C
245 CONTINUE
CMTBDO=(1.-FFRU)*CMTBF
PRINT 300,CMTBF,CMTBDO
```

(continued)

Figure A-9. (continued)

```
03040 300 FORMAT(/,"INITIAL SYSTEM MTBF=",F7.1,
03050+       "  INITIAL ORGANIC SYSTEM MTBD=",F7.1/)
03052 PRINT 3054,FRRD
03054 3054 FORMAT(T2,"ORGANIC FALSE PULL RATE=",F5.3/)
03060 PRINT 307,SETOO,SETOW
03070 307 FORMAT(*SYSTEM COST-ORGANIC,WARRANTY = $*,2F8.0,/)
03080 PRINT *,"     INITIAL     COST PER SPARE SUB"
03090 PRINT *,"SUB   MTBF    ORG.   WRNTY."
03100 DO 350 J=1,NLRU
03110 PRINT 340,J,YTF(J),CL(J),CLW(J)
03130 340 FORMAT(T2,I2,1X,F8.1,2F8.0)
03140 350 CONTINUE
03150C  PRINT BASE TYPE OPERATING HOURS AND SCHEDULE OF INSTALLS
03160 PRINT 1715
03170 1715 FORMAT(//T4,"OPERATING HOURS AND INSTALL SCHEDULE BY YEAR ",
03180+"FOR EACH BASE TYPE"/T2,"BASE",T8,"# OF",T14,"OP HR",T23,"ACTIVATED "
03190+"SITES AFTER N YEARS"/T2,"TYPE",T8,"SETS",T14,"PER MO",T23,"0",T29,"1",
03200+ T35,"2",T41,"3",T47,"4",T53,"5")
03210 DO 1736 II=1,NBX
03220 LBSL = NLBSL(II)
03230 PRINT 1722,II,NB(II),HM(II),(NSCH(JJ,II),JJ=1,6)
03240 1722 FORMAT(T4,I1,T7,I5,T13,F6.0,T20,6(I5,1X))
03250 IF(LBSL .LT. 2) GO TO 1735
03260 DO 1734 JJ=2,LBSL
03270 LBSI = (JJ-1)*5 + 2
03280 LBSF = LBSI + 4
03290 PRINT 1732, (NSCH(IJ,II),IJ=LBSI,LBSF)
03300 1732 FORMAT(T26,5(I5,1X))
03310 1734 CONTINUE
03320 1735 CONTINUE
03330 1736 CONTINUE
03340C  INITIALIZE DISCOUNT FUNCTION
03350 YY1 = 1./SQRT(1.0+DR)
03360 YY2 = 1.0/(1.0+DR)
03370C  COMPUTE DISCOUNT FACTORS FOR EACH YEAR
03380 DO 2042 II=1,NY
03390 DISC(II) = 1.0
03400 2042 CONTINUE
03410 IF(DR .LE. 0.) GO TO 2056
03420 DO 2054 II=1,NY
03430 YS = II - 1
03440 YF = YS + 1.0
03450 DISC(II) = DAVG(YS,YF)
03460 2054 CONTINUE
03470 2056 CONTINUE
03480 XY=NY
03490 DSCTW=DSCTOT=DSC1=DSC2=1.
03500 IF (DR.LE.0) GO TO 385
03510 Y1 =(1.+DR)**.5 $ Y1=1./Y1 $ Y2=1./(1.+DR)
03520 DSCTOT=Y1*(1.-Y2**XY)/(NY*(1.-Y2))
03530 385 CONTINUE
03540C
03550C  *CALCULATE FREQUENCY FACTORS FOR CORRECTIVE MAINTENANCE*
03560C
03570C  ORGANIC CM FREQUENCY FACTORS
03580 CMDL(1) = PSD
03590 CMDL(2) = PSD*(1.-POSD)
03600 CMDL(3) = CMDL(2)*PNRTSSD
03610 CMDM(1) = 1.0 - PSD
03620 CMDM(2) = CMD(1)*(1.-POMD) + PSD*(1.-POSD)*(1.-RTOKS-PNRTSSD)
03630 CMDM(3) = CMDM(2)*PNRTSMD
```

(continued)

Figure A-1. (continued)

```
C
C COMPUTE FACTORS TO MODIFY MEAN TIME BETWEEN FAILURES & FALSE PULL
C RATE AS SEEN AT THE BASE
C CHECK FOR NO SUBASSEMBLY SPARING
 STEST = PSD*(1.-POSD)
 IF(STEST .GT. 0.0) GO TO 3669
 ISUBD = 0
 GO TO 3671
 3669 CONTINUE
 ISUBD = 1
 BIDSD = (1.-FPRD)/(PSD*(1.-POSD))
 3671 CONTINUE
C CHECK FOR NO MODULE SPARING
 TMOD = ((1.-PSD)*(1.-POMD)+PSD*(1.-POSD)*(1.-PTOKS-PNRTSSD))
 IF(TMOD .GT. 0.0) GO TO 3677
 IMSPD = 0
 GO TO 3682
 3677 CONTINUE
 IMSPD = 1
 BIDMD = (1.-FPRD)/TMOD
 3682 CONTINUE
C
 PRINT *," "
 PRINT *," PRINT CODE"
 READ *,IPT
 JPT=IPT
 PRINT 431,NI,TOH
 431 FORMAT( /*TOT.# INSTALLS =*,I5,*  TOT.OPER.HRS. = *,F12.0/)
 433 CONTINUE
 DO 440 J=1,NLRU
 NILB(J)=0
 NM=NMOD(J)
 DO 440 I=1,NM
 NIMDAR(I,J) = 0
 440 NIMB(I,J) = 0
 DO 2244 J=1,NLRU
 DO 2242 K=1,NBS
 TINCD(J,K) = 0.0
 2242 CONTINUE
 2244 CONTINUE
C  INITIALIZE GROWTH CURVE; FIND GROWTH RATES FOR WARRANTY & ORGANIC
C  TI IS TIME AT WHICH INITIALE VALUE OF EACH INPUTED MTBF
 TI = 1000.
C  TF IS TIME AT WHICH EACH UNIT HAS REACHED THE PERCENTAGE GROWTH
C  THAT WAS INPUTED
 TF = 50000.
 TARG = TF/TI
C  CALCULATE GROWTH RATE FOR ORGANIC,BO
 THARG = 1. + PCTGO
 BO = ALOG(THARG)/ALOG(TARG)
C  FIND TIME AT WHICH MTBF SATURATES FOR ORGANIC,TOL
 IF(BO .GT. 0) GO TO 3987
 BOR = 0.
 GO TO 3989
 3987 CONTINUE
 BOR = 1./BO
 3989 CONTINUE
 TOL = TI*(1.+PLIM)**BOR
C  COMPUTE GROWTH FACTOR FOR ORGANIC FOR EACH YEAR OF LIFE CYCLE
 DO 11440 II=1,NY
 TS = OPHY(II)
```

(continued)

Figure A-9. (continued)

```
IF(II .GT. 1) GO TO 11426
T1 = 0.0
GO TO 11429
11426 T1 = OPHY(II-1)
11429 CONTINUE
GFO(II) = SF(T1,T2,TI,TOL,RO)
11440 CONTINUE
C FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQD FOR EACH BASE
C TYPE: ORGANIC
DO 11470 II=1,NBX
CALL NSPRB(NO(II),GFO,NCIB,II,1,NY)
11470 CONTINUE
C  FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQD FOR DEPOT:ORGANIC
CALL NSPRD(NOD,GFO,NCIY,1,NY)
FO = SF(0.,TOH,TI,TOL,RO)
446 GORG=FO*SMTBF
PRINT 448,GORG
448 FORMAT("AVERAGE ORGANIC GROWTH MTBF =",F7.1/)
DO 2718 J=1,NLRU
NM = NMOD(J)
IF(NM .LE. 0) GO TO 2714
DO 2712 I=1,NM
RXBF(I,J) = (NO(I,J)/XBF(I,J))*STF(J)
2712 CONTINUE
2714 CONTINUE
2718 CONTINUE
C  ** COMPUTE REQUIRED SPARES FOR BASE & DEPOT, ORGANIC **
C
DO 2820 J=1,NLRU
C  *COMPUTE MODULE SPARES*
NM = NMOD(J)
C  DETERMINE IF MODULE SPARES ARE REQUIRED
IF(IMSPO .EQ. 0) GO TO 2790
IF(NM .EQ. 0) GO TO 2790
IF(NRTSSD .EQ. 1) GO TO 2790
DO 2788 I=1,NM
C  CHECK IF DISCARD AT FAILURE (DAF)
IF(IDF(I,J) .LE. 0) GO TO 2780
RNSMB = 0.0
DO 2776 K=1,NBX
NGFO = NO(K)
NGFOP1 = NGFO + 1
RMTB = BIDMO*XBF(I,J)*GFO(NGFO)/NO(I,J)
RNB = NB(K)
INCIB = (NCIB(NGFO,K) + NCIB(NGFOP1,K))/2.*RNB
IF(INCIB .LT. .01) GO TO 2776
CALL SPARE(3,ISPT,IDS,RTOKM,TBRCO,TDRCMO,TOSS,TOSM,RNRTSSD,
+ RNRTSMO,RSUFF,TBRCO,H(K),INCIB,RMTB,TINC,SPARES)
TINCO(J,K) = TINCO(J,K) + RXBF(I,J)*TINC
NSMB(I,J) = NSMB(I,J) + ISPT
RNSMB = RNSMB + SPARES
2776 CONTINUE
LNSMB = RNSMB + .99
NSMB(I,J) = NSMB(I,J) + LNSMB
GO TO 2788
2780 CONTINUE
C  DAF MODULE SPARES
2783 NSMDAF(I,J) = TOH*NO(I,J)/(XBF(I,J)*BIDMO*GFO(NOD))
2788 CONTINUE
2790 CONTINUE
C  * COMPUTE SUBASSEMBLY SPARES *
C CHECK IF SUBASSEMBLY HAS NO MODULES BUT IS DEPOT REPAIRABLE
```

(continued)

Figure A-9. (continued)

```
04790 IF(CL(J) .LT. .01) GO TO 2820
4792C CHECK FOR NO SUBASSEMBLY SPARING
4794 IF(ISUBD .EQ. 0) GO TO 2820
04800 PNSLB = 0.0
04810 DO 2810 K=1,NBX
04820 NGFD = ND(K)
4825 NGFDP1 = NGFD + 1
04830 PMTB = BIDSD*YTF(J)*GFD(NGFD)
04835 PNB = NB(K)
04840 SNCIB = (NCIB(NGFD,K) + NCIB(NGFDP1,K))/2.*PNB
4852 IF(SNCIB .LT. .01) GO TO 2810
04860 CALL SPARE(JSPFD,ISPT,IDS,PTOKS,TBRCD,TDRCSD,TOSS,TOSM,PNRTSSD,
04870+ PNRTSMD,PSUFF,TBRCD,H(K),SNCIB,PMTB,TINCD(J,K),SPARES)
04880 NSLB(J) = NSLB(J) + ISPT
04890 PNSLB = PNSLB + SPARES
04900 2810 CONTINUE
04910 LNSLB = PNSLB + .99
04920 NSLB(J) = NSLB(J) + LNSLB
04930 2820 CONTINUE
04940 IF(IPT.LT.0) GO TO 705
04950 PRINT *,"  ORGANIC MAINTENANCE SPARES"
04960 PRINT *,"SUB   SPARES   PCT.     COST"
04970 705 CONTINUE
04980 CSORG=CREPM=CSDAF=CSLRU=VXLR=0.
04990 DO 770 J=1,NLRU
05000 MAX(J)=0
05010 PCT=(NSLB(J)*100.)/NI
05020 NAS=NSLB(J)
05030 NSLX(J)=-NAS
05040 CLS=CL(J)*NAS
05050 CSORG=CSORG+CLS
05060 CSLRU=CSORG
05070 IF(IPT.LT.0) GO TO 770
05080 PRINT 760,J,NSLB(J),PCT,CLS
05090 760 FORMAT(I3,I8,F9.2,F10.0)
05100 770 CONTINUE
05110 PRINT *," "
05120 IF(IPT.LE.0) GO TO 821
05130 PRINT *,"MODULE SPARES"
05140 PRINT *,"SUB  MOD   QTY   SPARES   PCT."
05150 821 CONTINUE
05160 DO 940 J=1,NLRU
05170 NM=NMOD(J)
05180 IF(NM.LE.0) GO TO 939
05190 DO 938 I=1,NM
05200 PCT = NSMB(I,J) + NSMDAF(I,J)
05210 PCT=(PCT*100.)/(NI*NQ(I,J))
05220 NTB=NSMB(I,J)+NSMDAF(I,J)
05230 VEM=VUM=0.
05240 NPM(I,J) = NTB
05250 KM = NTB/NQ(I,J)
05260 IF(IDF(I,J).LE.0) GO TO 880
05270 IF(NSLX(J).LE.0) GO TO 880
05280 IF(KM.GT.MAX(J)) MAX(J)=KM
05290 IF(MAX(J).GT.NSLX(J)) MAX(J)=NSLX(J)
05300 880 CONTINUE
05310 II=I
05320 IF(IDF(I,J).LE.0) II=-I
05330 IF(IPT.LE.0) GO TO 905
05340 PRINT 910,J,II,NQ(I,J),NPM(I,J),PCT
05350 905 CONTINUE
05360 910 FORMAT(T2,I2,I5,I6,I8,F9.2)
```

(continued)

Figure A-9. (continued)

```
      IF(IDF(I,J).LE.0) GO TO 920
C CHECK FOR EXCESS MODULES
      NEM=NO(I,J)*MAX(J)-NRM(I,J)
      IF(NEM.LE.0) GO TO 917
C FIND VALUE OF EXCESS MODULES
      VEM=NEM*VMOD*C(I,J)
C  IF MORE MODULES ON HAND THAN NEEDED, SET REQUIREMENTS TO ZERO
      IF(NRM(I,J) .LT. 0) NRM(I,J)=0
      VUM=NRM(I,J)*C(I,J)
      GO TO 918
  917 VUM=MAX(J)*NO(I,J)*C(I,J)
C  ACCOUNT FOR MODULES FROM DISASSEMBLED SUBASSEMBLIES
C BUY MODULES
  918 CREPM=CREPM+NRM(I,J)*C(I,J)-VEM-VUM
      GO TO 938
  920 NUDAF=MIN0(NO(I,J)*MAX(J),NRM(I,J))
      CCDAF=CCDAF+(NIMDAF(I,J)-NUDAF*PUDAF)*C(I,J)*DISCTOT
  938 CONTINUE
  939 CONTINUE
  940 CONTINUE
      DO 945 J=1,NLRU
      IF(NSLX(J).LE.0) GO TO 946
      NX=NSLX(J)-MAX(J)
      VXLR=VXLR+NX*CLW(J)*BMORT
  945 CONTINUE
  946 CSLRU=CSLRU-VXLR
      CSDRG=CSDRG-VXLR+CREPM+CCDAF
      IF(IPT.LT.0) GO TO 1001
      IF(NRT.EQ.1) GO TO 952
      PRINT *,"FOLLOWING SPARES COSTS ACCOUNT FOR VALUE OF ON-HAND ASSETS"
  952 PRINT 960,CSLRU
  960 FORMAT( ,*TOTAL COST OF SPARE SUBS =        $*,F8.0)
      PRINT 975,CREPM
  975 FORMAT(  *TOTAL COST OF SPARE REP.MODULES= $*,F8.0)
      PRINT 990,CCDAF
  990 FORMAT(  *TOTAL COST OF DAF MODULES =       $*,F8.0)
      PRINT 996,CSDRG
  996 FORMAT(/,*TOTAL SPARES & DAF MODULE COST=  $*,F8.0,/)
*     RIW SPARES
 1001 INP=0 $ IPT=JPT
      PRINT *,"WARRANTY PERIODS-TW,DEL,NR"
      READ *,TW,DEL,NR
 1004 IF(TW) 9999,2000,1005
 1005 DISCTW=DISC1=DISC2=1.
      PRINT *," "
      GO TO(4804,4808,4812) NWC
 4804 PRINT *," WARRANTY AT ORGANIZATIONAL,BASE & DEPOT LEVELS"
      GO TO 4814
 4808 PRINT *," WARRANTY AT BASE & DEPOT LEVELS"
      GO TO 4814
 4812 PRINT *," WARRANTY AT DEPOT LEVEL"
 4814 CONTINUE
      DISCTG=(1.+DR)**(-TG)
      IF(NR.GT.1) IPT=-1
11012 CONTINUE
       IF(DR.LE.0) GO TO 1020
      DISCTW=(1.+DR)**(-TW)
      IF(NY.LE.TW) GO TO 1015
      DISC2=(NY*DISCTOT-Y1*(1.-Y2**TW)/(1.-Y2))/(NY-TW)
 1015 DISC1=Y1*(1.-Y2**TW)/(TW*(1.-Y2))
 1020 [illegible]
C
```

(continued)

Figure A-9. (continued)

```
C  CHECK FOR NRTS + RTOK .GT. 1
JCH = PNRTSSW + RTOKS - .0001
IF(JCH .LT. 1) GO TO 1030
PNRTSSW = 1.0 - RTOKS
PRINT *,"NRTS SET TOO HIGH FOR SUBASSEMBLIES,WARRANTY"
1030 CONTINUE
JCH = PNRTSMW  + RTOKM -.0001
IF(JCH .LT. 1) GO TO 1040
PNRTSMW = 1.0 - RTOKM
PRINT *,"NRTS IS TOO HIGH FOR MODULES,WARRANTY"
1040 CONTINUE
C
C DETERMINE LEVEL OF REPAIR FOR MAINTENANCE CONCEPT AND SET FLAGS
NRTSSW = PNRTSSW+ RTOKS + .0001
JSRRW = 2
IF(NRTSSW .EQ. 1) JSRRW = 1
C COMPUTE FALSE PULL RATE
FPRW = PSW*(1.-PDSW)*(RTOKS+PNRTSSW*TGDSW)+
+        ((1.-PSW)*(1.-PDMW)+PSW*(1.-PDSW)*(1.-RTOKS-PNRTSSW))
+      *(RTOKM + PNRTSMW*TGDMW)
C  WARRANTY CM FREQUENCY FACTORS
WMDL(1) = PSW
WMDL(2) = PSW*(1.-PDSW)
WMDL(3) = WMDL(2)*PNRTSSW
WMDM(1) = 1.0 - PSW
WMDM(2) = WMDM(1)*(1.-PDMW) + PSW*(1.-PDSW)*(1.-RTOKS-PNRTSSW)
WMDM(3) = WMDM(2)*PNRTSMW
C
C CHECK FOR NO SUBASSEMBLY SPARING
ITEST = PSW*(1.-PDSW)
IF(ITEST .GT. 0.0) GO TO 6076
ISUBW = 0
GO TO 6081
6076 CONTINUE
ISUBW = 1
BIDSW = (1.-FPRW)/(PSW*(1.-PDSW))
6081 CONTINUE
C CHECK IF NO MODULE SPARING
TMOD = (1.-PSW)*(1.-PDMW)+PSW*(1.-PDSW)*(1.-RTOKS-PNRTSSW)
IF(TMOD .GT. 0.0) GO TO 6087
IMSRW = 0
GO TO 6092
6087 CONTINUE
IMSRW = 1
BIDMW = (1.-FPRW)/TMOD
6092 CONTINUE
C
C COMPUTE SYSTEM DEMANDS FOR WARRANTY
SMTBDW = (1.-FPRW)*SMTBF
C CALCULATE GROWTH RATE FOR WARRANTY,BW
THARG = 1. + PCTGW
BW = ALOG(THARG)/ALOG(TARG)
BM = -BW
C FIND TIME AT WHICH MTBF SATURATES FOR WARRANTY
IF(BW .GT. 0) GO TO 3978
BWR = 0.
GO TO 3982
3978 CONTINUE
BWR = 1./BW
3982 CONTINUE
TWL = TI*(1.+RLIM)**BWR
NTW = TW
C COMPUTE GROWTH FACTOR FOR WARRANTY FOR EACH YEAR OF WARRANTY
```

(continued)

Figure A-9. (continued)

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```
C   TWH IS THE NUMBER OF OPERATING HOURS AT TRANSITION
TWH = OPHY(NTW)
DO 12940 II=1,NTW
T2 = OPHY(II)
IF(II .GT. 1) GO TO 12928
T1 = 0.0
GO TO 12930
12928 T1 = OPHY(II-1)
12930 CONTINUE
GFW(II) = SF(T1,T2,TI,TWL,BW)
12940 CONTINUE
C
C   FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQUIRED FOR EACH
C   BASE TYPE: WARRANTY
DO 12975 II=1,NB
CALL NSPRB(NW(II),GFW,NCIB(II,1,NTW)
12975 CONTINUE
C
C FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQD FOR DEPOT: WARRANTY
CALL NSPRD(NWI,GFW,NCID,1,NTW)
C
C   COMPUTE GROWTH FACTOR FOR PERIOD (TW,NY)
NTWP1 = NTW + 1
DO 1 [illegible] II=NTWP1,NY
T2 = OPH [illegible] II
IF [illegible] 1 [illegible]
T1 [illegible]
[illegible]
[illegible]
[illegible]
GF [illegible] TI,TWH,TWL,FLIM,BD,BW)
[illegible]
C
C FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQD FOR EACH BASE TYPE:
C ORGANIC AFTER WARRANTY
DO 66[illegible] II=1,NB
CALL NSPRB(MO(II),GFWD,NCIB(II,NTWP1,NY)
66[illegible] CONTINUE
C   FIND YEAR IN WHICH MAXIMUM # OF SPARES ARE REQUIRED FOR PERIOD
C   (TW,NY) AT DEPOT
CALL NSPRD(NWOD,GFWD,NCID,NTWP1,NY)
NWODP1 = NWOD + 1
TWH = OPHY(NTW)
1036 FWD = SFLC(0.,TOH,TI,TWH,TWL,FLIM,BD,BW)
1037 CONTINUE
CILW=CIMW=CIAF=CDEC=0.
CMODW = CWDAF = 0.0
TWOT = 1.-TW/XY
AMORT = BMORT*TWOT
AMOD = VMOD*TWOT
IF(IFT.LT.0) GO TO 1012
PRINT 6764,IMTBDW
1011 FORMAT(/,"WARRANTY SPARES",/," SUB    SPARES    PCT.    COST")
PRINT 6765,FFRW
6764 FORMAT(/T2,"INITIAL WARRANTY SYSTEM MTBD=",F7.1)
PRINT 1011
6765 FORMAT( T2,"WARRANTY FALSE PULL RATE=",F5.3 )
1012 CONTINUE
DO 1160 J=1,NLRU
C
C COMPUTE SUPPLEMENTAL DEMANDS FOR WARRANTY
STD(J) = STF(J)*(1.-FFRW)
```

(continued)

Figure A-9. (continued)

```
      DO 5303 K=1,NE
      TINCW(J,K)=TINCWD(J,K) = 0.0
 5303 CONTINUE
C     ** COMPUTE REQUIRED SPARES FOR FAIL & DEPOT. WARRANTY **
C
      NAC(I) = 0
      NCLWD(J) = NCLET(J)=0
C     * COMPUTE MODULE SPARES *
      NM = NMOD(J)
      DO 5433 I=1,NM
      NIMW(I,J) =NNDAF(I,J)=NMMW(I,J)=NM(I,J)=NFM(I,J)=0
 5433 CONTINUE
C     DETERMINE IF MODULE SPARES ARE REQUIRED
      IF(IMSPR .EQ. 0) GO TO 4593
      IF(NM .EQ. 0) GO TO 4593
      IF(NFTIDW .EQ. 1) GO TO 4593
      DO 4576 I=1,NM
C     CHECK IF DISCARD AT FAILURE
      IF( IDF(I,J) .LE. 0) GO TO 4581
      FNIMW = .0
      DO 4573 K=1,NE
      NGFW = NW(K)
      NGFWP1 = NGFW + 1
      FMTB = FIDMW*DFF(I,J)*GFW(NGFW)/MD(I,J)
      FNE = NE(K)
      INCIB = (NCIB(NGFW,K) + NCIB(NGFWP1,K)) / 2.*FNE
 4572 IF(INCIB .LT. .01) GO TO 4573
      CALL SPARE(3,ISPT,IDI,RTOKM,TBRCW,TDRCMW,TDII,TDIM,FNFTIDW,
     +  FNFTIMW,RIDFF,TBRCW,H(K),INCIB,FMTB,TINC,SPARES)
      TINCW(J,K) = TINCW(J,K) + RDFF(I,J)*TINC
      NIMW(I,J) = NIMW(I,J) + ISPT
      FNIMW = FNIMW + SPARES
 4573 CONTINUE
      LNIMW = FNIMW + .99
      NIMW(I,J) = NIMW(I,J) + LNIMW
      FMAI = NIMW(I,J)
      CMDIW = CMDIW + FMAI*C(I,J)
      GO TO 4576
 4581 CONTINUE
C     DAF MODULES
      [illegible] = [illegible]*DFF(I,J)*FIDMW*GFW(NWD)
      [illegible] TAF + NNIAF(I,J)*C(I,J)*DIC1
 4576 CONTINUE
 4593 CONTINUE
C     [illegible] MODULE TYPE SUBASSEMBLY
      IF [illegible] GO TO 4621
C     [illegible] FOR NO SUBASSEMBLY SPARING
      IF [illegible] .EQ. [illegible] GO TO 4621
      FNSUW = .
C     * COMPUTE SUBASSEMBLY SPARES *
      DO 4620 K=1,NE
      NGFW = NW(K)
      NGFWP1 = NGFW + 1
      FMTB = FIDSW*STF(J)*GFW(NGFW)
      FNE = NE(K)
      INCIB = (NCIB(NGFW,K) + NCIB(NGFWP1,K)) / 2.*FNE
 7272 IF(INCIB .LT. .01) GO TO 4620
      CALL SPARE(ISPRW,ISPT,IDI,RTOKS,TBRCW,TDRCSW,TDII,TDIM,FNFTIDW,
     +  FNFTIMW,FIDFF,TBRCW,H(K),INCIB,FMTB,TINCW(J,K),SPARES)
      NSUW(J) = NSUW(J) + ISPT
      FNSUW = FNSUW + SPARES
 4620 CONTINUE
```

(continued)

Figure A-9. (continued)

```
07390 LNILM = FNILM + .99
07400 NILM(J) = NILM(J) + LNILM
07410 4821 CONTINUE
07420 FNAI = NILM(J)
07430 CILM = CILM + FNAI*CLM(J)
07440 PCT = (NILM(J)*100.)/NI
07450 CLE(J) = FNAI*CLM(J)
07460 NIL(J) =NILM(J)
07470 IF(NTM .EQ. 0) GO TO 4830
07380C ** COMPUTE REQUIRED SPARES AFTER TRANSITION **
07390C
07400C * COMPUTE MODULE SPARES *
07410C DETERMINE IF MODULE SPARES ARE REQUIRED
7415 IF(IMSPO .EQ. 0) GO TO 4796
07420 IF(NM .EQ. 0) GO TO 4796
07430 IF(NRTIIM .EQ. 1) GO TO 4796
07440 DO 4794 I=1,NM
07450C CHECK FOR DRF
07460 IF( IDF(I,J) .LE. 0) GO TO 4794
07470 FNMM = 0.0
07480 DO 4792 K=1,NB
7485 MWOD = MWD(K)
7487 MWODP1 = MWOD + 1
07490 PMTB = BIDMO*DF(I,J)*RFWD(MWOD)/MD(I,J)
07495 PNB = NB(K)
07500 INCIB = (NCIB(MWOD,K) + NCIB(MWODP1,K))/2.*PNB
7512 IF(INCIB .LT. .01) GO TO 4792
07520 CALL SPARE(3,IIPT,IDI,RTOKM,TBRCD,TDRCMD,TDII,TDIM,PNRTIID,
07530+ PNRTIMD,RIUFF,TBRCD,H(K),INCIB,PMTB,TINC,SPARES)
07540 TINCWD(J,K) = TINCWD(J,K) + PMBF(I,J)*TINC
07550 NMW(I,J) = NMW(I,J) + IIPT
07560 FNMW = FNMW + SPARES
07570 4792 CONTINUE
07580 LNMW = FNMW + .99
07590 NMW(I,J) = NMW(I,J) + LNMW
07600 4794 CONTINUE
07610 4796 CONTINUE
07620C * COMPUTE SUBASSEMBLY SPARES *
07630 IF( IL(J) .LT. .01) GO TO 4830
07632C CHECK FOR NO SUBASSEMBLY SPARING
7634 IF(ISUBO .EQ. 0) GO TO 4830
07640 FNILBT = 0.
07650 DO 4820 K=1,NB
7654 MWOD = MWD(K)
7656 MWODP1 = MWOD + 1
07660 PMTB = BIDSO*STF(J)*RFWD(MWOD)
07665 PNB = NB(K)
07670 INCIB = (NCIB(MWOD,K) + NCIB(MWODP1,K))/2.*PNB
7682 IF(INCIB .LT. .01) GO TO 4820
07690 CALL SPARE(JIFRO,IIPT,IDI,RTOKI,TBRCD,TDRCSD,TDSI,TDIM,PNRTIID,
07700+ PNRTIIM,RIUFF,TBRCD,H(K),INCIB,PMTB,TINCWD(J,K),SPARES)
07710 NILBT(J) = NILBT(J) + IIPT
07720 FNILBT = FNILBT + SPARES
07730 4820 CONTINUE
07740 LNILBT = FNILBT + .99
07750 NILBT(J) = NILBT(J) + LNILBT
07760 4830 CONTINUE
07770 NIL(J) = NIL(J) - NILBT(J)
07780* CHECK IF MORE SUBS HAVE TO BE BOUGHT
07790 IF(NIL(J) .GE.0) GO TO 1098
07800* BUY NEEDED SUBS
07810 C=45 (ILH=ILM-NILX(J)*DIC*CLM(J)
```

(continued)

Figure A-9. (continued)

```
1099 IF(IPT.LT.0) GO TO 1103
1100 PRINT 1101,J,NILW(J),PCT,CLB(J)
1101 FORMAT(T2,I2,3X,I6,F8.2,F10.0)
*    MODULE SPARES
1103 CONTINUE
IF(NM.LE.0) GO TO 1160
DO 1155 I=1,NM
FD=GFWD(NMOD) GFD(NOD)
*  CALCULATE TOTAL MODULE REQUIREMENTS
IF(IDF(I,J).LE.0) GO TO 1125
C  CHECK IF MORE REPAIRABLE MODULES HAVE TO BE BOUGHT
NIMX(I,J) = NIMW(I,J) - NMW(I,J)
IF(NIMX(I,J) .GT. 0) GO TO 5088
CIMW = CIMW - NIMX(I,J)*C(I,J)*DISCTW
5088 CONTINUE
GO TO 1131
1125 NIMA=((N-TW) N))*TOH*NO(I,J) (GFWD(NMOD)*XBF(I,J)*BIIMD)
CDAF=CDAF+NIMA*C(I,J)*DISC2
*  DETERMINE # SUBS TO BE DISASSEMBLED
1131 CONTINUE
KM = NMW(I,J)
NRM(I,J)=KM
KM=KM/NO(I,J)
IF(IDF(I,J).LE.0) GO TO 1153
C  CHECK IF MORE REPAIRABLE MODULES ARE REQUIRED
IF(NIMX(I,J) .GT. 0) GO TO 1155
IF(NILX(J).LE.0) GO TO 1155
*  MAX(J) IS # OF J-SUBS TO DISASSEMBLE
IF(KM.GT.MAX(J)) MAX(J)=KM
IF(MAX(J).GT.NILX(J)) MAX(J)=NILX(J)
GO TO 1155
1153 NRM(I,J)=NIMA
1155 CONTINUE
1160  CONTINUE
IF(IPT .LT. 0) GO TO 6530
PRINT *," "
PRINT *,"DO YOU WANT MODULE SPARES DATA PRINTED, 1-YES, 0-NO"
READ *,IPMOD
IF(IPMOD .LE. 0) GO TO 6530
PRINT *," "
PRINT *,"MODULE SPARES"
PRINT *,"SUB  MOD   QTY   SPARES   PCT."
DO 6528 J=1,NLRU
NM = NMOD(J)
DO 6526 I=1,NM
MPCT = NIMW(I,J) + NWIAF(I,J)
PCTM = MPCT
PCT = PCTM*100./(NI*NO(I,J))
II = I
IF( IDF(I,J) .LE. 0) II = -I
PRINT 910,J,II,NO(I,J),MPCT,PCT
6526 CONTINUE
6528 CONTINUE
6530 CONTINUE
CIM = CILW + CMODW
VSLF =  DDAF = 0
DO 1272 J=1,NLRU
IF(NILX(J).LE.0) GO TO 6595
N =NILX(J)-MAX(J)
*  VALUE OF EXCESS COMPLETE SUBASSEMBLIES
V=N *CLW(J)*FACSFT
VSLF=VSLF+V
```

(continued)

Figure A-9. (continued)

```
08450 6595 CONTINUE
08460 NM=NMOD(J)
08470 VEM=VUM=0.
08480 IF(NM.LE.0) GO TO 1271
08490C  VALUE OF MODULES IN DISASSEMBLED SUBASSEMBLIES
08500 DO 1270 I=1,NM
08510 IF(NIM(I,J) .LT. 0) GO TO 5390
08520C  VALUE OF EXCESS REPAIRABLE MODULES
08530 VEM = NIM(I,J)*C(I,J)*AMOI
08540 GO TO 1260
08550 5390 CONTINUE
08560 IF(IDF(I,J).LE.0) GO TO 1265
08570 NEM=NO(I,J)*MAX(J)-NRM(I,J)
08580 IF(NEM.LE.0) GO TO 1255
08590*  HAVE EXCESS REPAIRABLE MODULES
08600 VEM=NEM*AMOD*C(I,J)
08610 VUM=NRM(I,J)*C(I,J)*DISTM
08620 GO TO 1260
08630*  NO EXCESS REPAIRABLE MODULES
08640 1255 VUM=MAX(J)*NO(I,J)*C(I,J)*DISTM
08650 1260 CONTINUE
08660 CDEC=CDEC+VEM+VUM
08670 GO TO 1270
08680*  VALUE OF USEABLE DAF MODULES
08690 1265 NUDAF=MIN0(NO(I,J)*MAX(J),NRM(I,J))
08700 VEDAF=NUDAF*C(I,J)*FUDAF*DIS2
08710 CDEC=CDEC+VEDAF
08720 DDAF=DDAF+VEDAF
08730 1270 CONTINUE
08740 1271 CONTINUE
08750 1272 CONTINUE
08760 1273 CONTINUE
08770C  COMPUTE REQUIRED SPARES COST FOR WARRANTY & ORG. AFTER WARTY
08780C ADD REP MOD COST
08790 CRMOD = CMODW + CSMW
08800C  ADD DAF MOD COST
08810 CDAFT = CWDAF + CDAF
08820C TOTAL REQUIRED COST FOR SPARES
08830 CTOTR = CSLW + CRMOD + CDAFT
08840C  COMPUTE VALUE OF EXCESS SPARES
08850C  VALUE OF REP MODS
08860 CMODV = CDEC - DDAF
08870C  TOTAL VALUE OF EXCESS SPARES
08880 XT = CDEC + VXLR
08890C SUBASSEMBLIES
08900 CSLWN = CSLW - VXLR
08910C  REP MODS
08920 T2NDF = CRMOD - CMODV
08930C  DAF
08940 CDAF2 = CDAFT- DDAF
08950C  TOTAL NET COST OF SPARES
08960 TOT2 = CSLWN + T2NDF + CDAF2
08970 WINDF = TOT2 - CDAF2
08980 IF (IFT.LT.0) GO TO 6000
08990 PRINT *," "
09000 PRINT *,"WARRANTY SPARES COSTS"
09010 PRINT *,"                        SUB      REP.MOD.    DAF MOD.     TOTAL"
09020 CDAFW = CDAF + CMODW
09030 PRINT 1310,CSLW,CRMOD,CDAFT,CTOTR
09040 1310 FORMAT(*REQUIRED*,4(2X,F9.0))
09050 PRINT 1315,VXLR,CMODV,DDAF,XT
09060 1315 FORMAT(*VALUE    *,4(2X,F9.0))
```

(continued)

Figure A-9. (continued)

```
 PRINT 1320,CSLWN,T2NDF,CDAF2,TOT2
 1320 FORMAT(*NET COST*,4(2X,F9.0))
 PRINT 1360,DSC1,DSCTW,DSC2,DSCTOT
 1360 FORMAT(/,T5,"DISCOUNT FACTORS",/,"DSC1,DSCTW,DSC2,DSCTOT",
+ 4F7.4,/)
 5550 CONTINUE
 6000 CONTINUE
*    SET ACQUISITION
 ACO=ACW=0.
 DO 6065 J=1,NLRU
 ACO=ACO+CINSO(J)*NI
 ACW=ACW+CINSW(J)*NI
 6065 CONTINUE
* AGE
 AGO=AGBO*NBS+AGDO*(1-NPT)*AGBW*NBS
 AGWO=AGBW*NBASE(NTWP1)+(AGBO*NBS+AGDO-AGBW*NBASE(NTWP1))*DSCTW
 AGW=AGBW*NBS*NPT
* AGE SUPPORT
 AGSPO=(AGBO*NBS*PAGB+AGDO*PAGD)*NY*DSCTOT
 AGSPW=AGBW*NBASE(NTWP1)*TW*PAGB*DSC1
+     +(AGBO*NBS*PAGB+AGDO*PAGD)*(NY-TW)*DSC2
*    TRAINING
 TRO=((WTBO-WTBW*(1-NPT))*NBS+WTDO)*TCPW
+ +(WTBO*NBS+WTDO)*TCPW*NY*DSCTOT*RTP
 TRWO=(WTBW*NBASE(NTWP1)+(WTBO*NBS-WTBW*NBASE(NTWP1))*DSCTW)
+ *TCPW +WTDO*DSCTW*TCPW
 TRWO=TRWO+(WTBW*TW*NBASE(NTWP1)*DSC1+WTBO*(NY-TW)*NBS*DSC2
+   +WTDO*(NY-TW)*DSC2)*RTP*TCPW
 TRW=WTBW*NBS*TCPW*(NPT+RTP*NY*DSCTOT)
*   DATA
 DATO=DTAO-(1-NPT)*DTAW
 DATWO=DTAW*NPT+(DTAO-DTAW)*DSCTW
 DATW=DTAW*NPT
 BWM  = -BW
C COMPUTE THE AVERAGE GROWTH FACTOR FOR WARRANTY OVER (0,TW)
 FW = SF(0.,TWH,TI,TWL,BW)
C COMPUTE THE AVERAGE GROWTH FACTOR OVER THE PERIOD (TW+1,NY)
 IF(NTW .NE. NY) GO TO 15798
 FOFW = (TI**BWM)*(TOH**BW)
 GO TO 15800
 15798 CONTINUE
 FOFW = SFWO(TWH,TOH,TI,TWH,TWL,PLIM,BC,BW)
 15800 CONTINUE
 CIMO=NRCO*CIM*NY*DSCTOT
 CIMW=NRCW*CIM*TW*DSC1
+ +NRCO*CIM*(NY-TW)*DSC2
 CINDF=CSORG-CSDAF
C   **** CORRECTIVE MAINTENANCE ****
C COMPUTE TOTAL CORRECTIVE MAINTENANCE COST, ORGANIC
 TACMCO = 0.
 DO 6334 KK=1,NY
 DTACMCO = 0.
 DO 6305 II=1,2
 DO 6300 LL=1,NBS
C  COMPUTE DEMAND DRIVEN AVERAGE CORRECTIVE MAINTENENCE FOR THE FIRST
C  TWO LEVELS PER MONTH IN THE YEAR OF INTEREST
 ACMHMO(II,LL) = HM(LL)*(CMDL(II)*ACMMLO(II) + CMDM(II)*ACMMMO(II))/
+    (MTBDO*GFO(KK))
C  COMPUTE DEMAND DRIVEN CM MANHOURS FOR TWO LEVELS PER BASE TYPE
C  REF YEAR
 DCM(II,LL) = ACMHMO(II,LL)*(NCIB(KK,LL)+NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE MAXIMUM BETWEEN DEMAND DRIVEN & FIXED
```

(continued)

Figure A-9. (continued)

```
DXD(II,LL) = AMAX1(DXD(II,LL),AFCMHB(II,LL))
DTACMCD = DTACMCD + DXD(II,LL)*AALFCM(II)
6300 CONTINUE
6305 CONTINUE
C  COMPUTE DEPOT CM MANHOURS PER MONTH FOR YEAR OF INTEREST
SUM = 0.
DO 6319 LL=1,NBX
SUM = SUM + HM(LL)*(NCIB(KK,LL) + NCIB(KK+1,LL))*.5*NB(LL)
6319 CONTINUE
CINH(KK) = SUM
C  COMPUTE DEMAND DRIVEN DEPOT CM MANHOURS PER MONTH FOR KK YEAR
SUMDEP = SUM*(CMDL(3)*ACMMLD(3) + CMDM(3)*ACMMMD(3))/
+   (CMTBDD*GFD(KK))
C  CHOOSE BETWEEN DEMAND DRIVEN AND FIXED
SUMDEP = AMAX1(SUMDEP,AFCMHD)
TACMCD = (DTACMCD + AALFCM(3)*SUMDEP)*DISC(KK)*12. + TACMCD
6334 CONTINUE
C   **COMPUTE TOTAL CORRECTIVE MAINTENANCE COST, WARRANTY**
TACMCW = 0.0
DO 6390 KK=1,NTW
DTACMCW = 0.0
C  CHECK FOR TYPE OF WARRANTTY CONCEPT
IF(NWC .EQ.1) GO TO 6390
DO 6382 II=1,2
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(II .EQ. 1 .AND. NWC .EQ. 2) GO TO 6382
DO 6378 LL= 1,NBX
C  COMPUTE DEMAND DRIVEN AVERAGE MANHOURS FOR EACH LEVEL OF MAINTENANCE
C  PER BASE TYPE PER MONTH IN THE YEAR OF INTEREST
ACMHMW(II,LL)=HM(LL)*(WMDL(II)*ACMMLW(II)+WMDM(II)*ACMMMW(II))/
+                 (CMTBDW*GFW(KK))
C  COMPUTE DEMAND DRIVEN CM MANHOURS FOR EACH LEVEL OF MAINTENANCE
C  PER BASE TYPE PER MONTH PER YEAR
DXW(II,LL)= ACMHMW(II,LL)*(NCIB(KK,LL)+NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE MAXIMUM BETWEEN DEMAND DRIVEN & FIXED
DXW(II,LL) = AMAX1(DXW(II,LL),AFCMHB(II,LL))
DTACMCW = DTACMCW + DXW(II,LL)*AALFCM(II)
6378 CONTINUE
6382 CONTINUE
TACMCW = 12.*DTACMCW*DISC(KK) + TACMCW
6390 CONTINUE
C  ** COMPUTE TOTAL CORRECTIVE MAINTENENCE COST,ORGANIC AFTER WARANTY**
TACMCWD = 0.0
NTWP1 = NTW + 1
DO 6443 KK=NTWP1,NY
DELTA = 0.0
DO 6424 II=1,2
DO 6422 LL=1,NBX
C  COMPUTE DEMAND DRIVEN MANHOURS FOR EACH MAINTANANCE LEVEL PER BASE
C  TYPE PER MONTH IN THE YEAR OF INTEREST
ACMHMWD(II,LL)= HM(LL)*(CMDL(II)*ACMMLD(II)+CMDM(II)*ACMMMD(II))/
+                  (CMTBDD*GFWD(KK))
C  COMPUTE DEMAND DRIVVEN CM MANHOURS PER MAINTENANCE LEVEL PER BASE
C  TYPE PER MONTH PER YEAR
DXWD(II,LL)= ACMHMWD(II,LL)*(NCIB(KK,LL)+NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
DXWD(II,LL)= AMAX1(DXWD(II,LL),AFCMHB(II,LL))
DELTA = DELTA +DXWD(II,LL)*AALFCM(II)
6422 CONTINUE
6424 CONTINUE
C  COMPUTE DEPOT CM MANHOURS PER MONTH FOR YEAR OF INTEREST
```

(continued)

Figure A-9. (continued)

```
C COMPUTE DEMAND DRIVEN DEPOT CM MANHOURS PER MONTH FOR YEAR OF INTEREST
SUMDEP = CINH(KK)*(CMDL(3)*ACMMLO(3)+CMDM(3)*ACMMMO(3))/
+              (MTBDO*GFWO(KK))
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
SUMDEP = AMAX1(SUMDEP,AFCMHD)
TACMCWO = 12.*(DELTA+AALRCM(3)*SUMDEP)*DISC(KK) + TACMCWO
6443 CONTINUE
C  CALCULATE TOTAL CM COST FOR WARRANTY AND ORGANIC AFTER WARRANTY
TACM = TACMCW + TACMCWO
C          ******** PREVENTIVE MAINTENANCE ********
C  COMPUTE TOTAL PREVENTIVE MAINTENCNCE COST, ORGANIC
TAPMCO = 0.
DO 6492 KK=1,NS
DELTA = 0.0
DO 6477 II=1,2
DO 6475 LL=1,NBX
C  COMPUTE DEMAND DRIVEN PM MANHOURS PER BASE TYPE PER LEVEL OF
C  MAINTENANCE PER MONTH
DS = AM(LL)*PMRO(II)*(NCIB(KK,LL) +NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE BETWEEN DEMAND DRIVEN AND FIXED
DS = AMAX1(DS,AFPMMB(II))
DELTA = DELTA + DS*AALRPM(II)
6475 CONTINUE
6477 CONTINUE
C  COMPUTE DEPOT PM MANHOURS PER MONTH FOR YEAR OF INTEREST
C COMPUTE DEMAND DRIVEN DEPOT PM MANHOURS PER MONTH FOR YEAR OF INTEREST
DSD = PMRO(3)*CINH(KK)
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
SD = AMAX1(DSD,AFPMMD)
TAPMCO = TAPMCO+ 12.*(DELTA+SD*AALRPM(3))*DISC(KK)
6492 CONTINUE
C  *COMPUTE TOTAL PREVENTIVE MAINTENANCE COST, WARRANTY
TAPMCW = 0.0
DO 6539 KK=1,NTW
DELTA = 0.0
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(NWC .EQ. 1) GO TO 6539
DO 6529 II=1,2
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(II.EQ.2 .AND. NWC .EQ.2) GO TO 6529
DO 6527 LL=1,NBX
C COMPUTE DEMAND DRIVEN PM MANHOURS PER BASE TYPE PER MAINTENANCE LEVEL
C PER MONTH
SDD = AM(LL)*PMRW(II)*(NCIB(KK,LL)+NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
SDD = AMAX1(SDD,AFPMMB(II))
DELTA = DELTA + SDD*AALRPM(II)
6527 CONTINUE
6529 CONTINUE
TAPMCW = TAPMCW + 12.*DELTA*DISC(KK)
6539 CONTINUE
C  *COMPUTE TOTAL PREVENTIVE MAIINTENANCE COST, ORGANIC AFTER WARRANTY
TAPMCWO = 0.0
DO 6582 KK= NTWP1,NS
DELTA = 0.0
DO 6565 II=1,2
DO 6564 LL=1,NBX
C  COMPUTE DEMAND DRIVEN PM MANHOURS PER BASE TYPE PER MAINTENANCE
C  LEVEL PER MONTH
DS = AM(LL)*PMRO(II)*(NCIB(KK,LL) + NCIB(KK+1,LL))*.5*NB(LL)
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
DS = AMAX1(DS,AFPMMB(II))
```

(continued)

Figure A-9. (continued)

```
DELTA = DELTA + DZ*AALRPM(II)
6564 CONTINUE
6568 CONTINUE
C  COMPUTE DEPOT PM MANHOURS PER MONTH FOR YEAR OF INTEREST
C  COMPUTE DEMAND DRIVEN PM MANHOURS PER MO. PER YR. OF INTEREST
DZD = PMPW(3)*CINH(KK)
C  CHOOSE BETWEEN DEMAND DRIVEN & FIXED
ZD = AMAX1(DZD,APPMMD)
TARMCWO = TARMCWO + 12.*(DELTA +ZD*AALRPM(3))*DISC(KK)
6582 CONTINUE
C  **** COMPUTE TOTAL PREVENTIVE MAINTENANCE COST, WRTY & OPS AFTER WRTY
TARM = TARMCW + TARMCWO
C  **** RIW FIXED PRICE ESTIMATE ****
C  **COMPUTE TOTAL CORRECTIVE MAINTENANCE COST TO CONTRACTOR**
RIWCM = 0.
IF(RIK .GT. 0.0) GO TO 9238
RIW =RIWFF
GO TO 9722
9238 CONTINUE
RDF = ((1.+RIK)**TW)*(1.+RFT)
DO 6672 KK=1,NTW
DELTA = 0.
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(NWC .EQ. 3) GO TO 6656
DO 6654 II=1,2
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF( II .EQ. 1 .AND. NWC .EQ. 2) GO TO 6654
C COMPUTE AVERAGE MANHOURS FOR EACH LEVEL OF MAINTENANCE PER BASE
C TYPE PER MONTH PER YEAR
DO 6652 LL=1,NBX
CCMAMW = AM(LL)*(WMDL(II)*CCMML(II) + WMDM(II)*CCMMM(II))
+              (IMTBIW*GFW(KK))
DCW = CCMAMW*(NCIB(KK,LL) + NCIB(KK+1,LL))*NB(LL)*.5
DCW = AMAX1(DCW,CFCMHB(II))
DELTA = DELTA + DCW*CALRCM(II)
6652 CONTINUE
6654 CONTINUE
6656 CONTINUE
C  COMPUTE DEPOT CM MANHOURS PER MONTH FOR KK YEAR
WMDD = CINH(KK)*(WMDL(3)*CCMML(3)+WMDM(3)*CCMMM(3))
+          (IMTBDW*GFW(KK))
CMDD = AMAX1(WMDD,CMCMHD)
RIWCM = RIWCM + (DELTA + CALRCM(3)*CMDD)*DISC(KK)*12.
6672 CONTINUE
C  ** COMPUTE TOTAL PREVENTIVE MAINTENANCE COST TO CONTRACTOR **
RIWPM = 0.
DO 6748 KK=1,NTW
DELTA = 0.
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(NWC .EQ. 3) GO TO 6736
DO 6728 II=1,2
C  CHECK FOR TYPE OF WARRANTY CONCEPT
IF(II .EQ. 1 .AND. NWC .EQ. 2) GO TO 6728
DO 6724 LL=1,NBX
C  COMMPUTE PM MANHOURS PER BASE TYPE PER MAINTENENCE LEVEL PER MONTH
DZ = AM(LL)*PMPW(II)*(NCIB(KK,LL) + NCIB(KK+1,LL))*NB(LL)*.5
DZ = AMAX1(DZ,CFPMMB(II))
DELTA = DELTA + DZ*CALRPM(II)
6724 CONTINUE
6728 CONTINUE
C  COMPUTE DEPOT PM MANHOURS PER MONTH FOR YEAR OF INTEREST
6736 CONTINUE
```

(continued)

Figure A-9. (continued)

```
11540 DSD = PMRM(3)*CINH(KK)
11550 DSD =AMAX1(DSD,PFMMD)
11560 RIWPM = RIWPM + 12.*(DELTA + DSD*CALPPM(3))*DISC(KK)
11570 674  CONTINUE
11580C   INCLUDE % COST FOR DATA AND ADMINISTRATION
11590 RIWT = (RIWCN + RIWPM)*(1.+DTP)
11600C    COMPUTE OTHER YEARLY COSTS TO CONTRACTOR
11610 RIWY = YCOTHW*TW*DSC1
11620C         TOTAL RIW COST
11630 RIW = RDP*(RIWT + RIWY + RIWFP)
11640 9722 CONTINUE
11650 6425 WPPD=RIW*100. /(SETOW*TW*(NCIY(NTW)+NCIY(NTWP1))*.5)
11660 IF(NP.GT.1) GO TO 6453
11670 PRINT *," "
11680 PRINT 6444,TW,RIW
11690 6444 FORMAT(F4.1," YEAR WARRANTY PRICE",7X,F10.0,2X,F10.0)
11700 PRINT 6450,WPPD
11710 6450 FORMAT(" PCT/YR PER INSTALLED SET",3X,F5.2,8X,F5.2/)
11720 6453 CONTINUE
11730 NTG = TG
11740 TTG = DPHY(NTG)
11745 TTGM6 = (TTG + DPHY(NTG-1))*.5
11750 TGTW = TG - TW
11755 IF(TGTW) 11760,11760,11780
11760 11760 CONTINUE
11765 GMG = SF(TTGM6,TTG,TI,TWL,BW)
11770 GO TO 11800
11780 11780 CONTINUE
11790 GMG = SFWO(TTGM6,TTG,TI,TWH,TWL,PLIM,BO,BW)
11800 11800 CONTINUE
11830 CSGW=0.
11840*     CONSIGNMENT SPARES
11850 IF(TW.LT.TG) GO TO 6599
11860 IF(GSET.LE.0) GO TO 6599
11870 DO 6598 J=1,NLRU
11880 PBF=SMTBDW/YTD(J)
11890 GMTBF=GSET/PBF
11900 X=GMTBF/(YTF(J)*GMG) -1.
11910 IF(X.LE.0.) GO TO 6598
11920 IF(X.GT.1.) X=1.
11930 CSGW=CSGW-X*CLW(J)*TSP(J)*NI*DSCTG
11940 6598 CONTINUE
11950 6599 XOTHO=YOTHO*NY*DSCTOT+OTHO
11960 XOTHWO=(OTHW*TW*DSC1+YOTHO*(NY-TW)*DSC2
11970+   + OTHWO+CTRANS*DSCTW+RIW*OWF
11980 XOTHW=YOTHW*NY*DSCTOT+OTHW+RIW*OWF
11990 TOTO=ACO+AGO+AGSPO+TRO+DATO+TACMCO+TAPMCO
12000+ +CSOPG+CIMO+XOTHO
12010 TOTW=ACW+AGW+AGSPW+TRW+DATW
12020+   +TACM+TAPM+CSW+RIW
12030+ +CIMW+CSGW+XOTHW+CWDAF
12040 TOTWO=ACW+AGWO+AGSPW+TRWO+DATWO
12050+ +TACM+TAPM+TOT2+RIW
12060+   +CIMW+CSGW+XOTHWO
12070 GW=FW*SMTBF
12080 GOFW=FOFW*SMTBF
12090 GWO=FWO*SMTBF
12100 WIL=TOTO-TOTWO
12110 IF(NP.LT.2) GO TO 6670
12120 IF(INF.GT.0) GO TO 6650
12130 PRINT 6647,TOTO
12140 6647 FORMAT(/" TOTAL ORGANIC LCC = $",F10.0/)
```

(continued)

Figure A-9. (continued)

```
12150 PRINT 12155
12155 12155 FORMAT("WRNTY YRS.       WRNTY LCC    SAVINGS/LOSS  WRNTY ",
12156+                  1X,"PRICE  AVG.MTBF")
12160 6650 CONTINUE
12170 INF=INF+1
12180 PRINT 6655,TW,TOTWO,WIL,PIW,GWO
12190 6655 FORMAT(T3,F5.2,7X,F11.0,3X,F10.0,5X,F10.0,3X,F6.0)
12200 IF(INF.GE.NF) GO TO 6663
12210 TW=TW+DEL
12220 GO TO 11012
12230 6663 IF(TW.NE.0) GO TO 6800
12240 6664 WIL=TOTO-TOTW
12250 PRINT 6666,TOTW,WIL
12260 6666 FORMAT(◆FULL W◆,10X,F9.0,3X,F10.0)
12270 GO TO 6800
12280 6670 NF=0
12290 PRINT ◆," "
12300 PRINT 12302
12302 12302 FORMAT( 26X,"ORGANIC    WRNTY/ORG   FULL WRNTY")
12310 IF(TW.NE.NY) GO TO 6760
12320 PRINT 6705,ACO,ACW,ACW
12330 6705 FORMAT(◆ACQUISITION◆,14X,3F11.0)
12340 CINDF=CIORG-CCDAF
12350 PRINT 6708,CINDF,WINDF,CIW
12360 6708 FORMAT ("INITIAL SPARING",9X,3F11.0)
12370 PRINT 6710,CCIAF,CDAF2,CWDAF
12380 6710 FORMAT("REPLENISHMENT SPARES",4X,3F11.0)
12390C PRINT 6713,ONO,ONW,ONW
12400 6713 FORMAT(◆ON EQ.M ◆,3F11.0)
12410C PRINT 6717,OFFO,OFFW,OFFW
12420 PRINT 6718,TACMCO,TACM,TACM
12430 6718 FORMAT("CORRECTIVE MAINTENANCE",2X, 3F11.0)
12440 PRINT 6720,TAPMCO,TAPM,TAPM
12450 6720 FORMAT( "PREVENTIVE MAINTENANCE",2X, 3F11.0)
12460 6717 FORMAT(◆OFF EQ.M◆,3F11.0)
12470 PRINT 6719,PIW,PIW
12480 6719 FORMAT("WARRANTY PRICE",21X,2F11.0)
12490 PRINT 6722,AGO,AGWO,AGW
12500 6722 FORMAT(◆AGE◆,21X      ,3F11.0)
12510 PRINT 6725,AGSPO,AGSPW,AGSPW
12520 6725 FORMAT("AGE SUPPORT",13X,3F11.0)
12530 PRINT 6730,TRO,TRWO,TRW
12540 6730 FORMAT(◆TRAINING◆,16X,3F11.0)
12550 PRINT 6735,DATO,DATWO,DATW
12560 6735 FORMAT(◆DATA◆,20X,3F11.0)
12570 PRINT 6737,CIMO,CIMW,CIMW
12580 6737 FORMAT("INVENTORY MANAGEMENT",4X,3F11.0)
12590 PRINT 6739,CIGW,CIGW
12600 6739 FORMAT("MTBF GUARANTEE",21X,2F11.0)
12610 PRINT 6742,XOTHO,XOTHWO,XOTHW
12620 6742 FORMAT(◆OTHER◆,19X,3F11.0,/)
12630 PRINT 6755,TOTO,TOTWO,TOTW
12640 6755 FORMAT(◆TOTAL◆,19X,3F11.0,/)
12650 PRINT 6758,GW
12660 6758 FORMAT(/,◆AVG. MTBF=◆,F7.1/)
12670 GO TO 6800
12680 6760 CONTINUE
12690 PRINT 6705,ACO,ACW
12700 PRINT 6708,CSNDF,WSNDF
12710 PRINT 6710,CCIAF,CDAF2
12720C PRINT 6713,ONO,ONW
12730C PRINT 6717,OFFO,OFFW
```

(continued)

Figure A-9. (continued)

```
      PRINT 6718,TACMCD,TACM
      PRINT 6720,TAFMCD,TAFM
      PRINT 6719,FIW
      PRINT 6722,AGD,AGWD
      PRINT 6725,AGIFD,AGIFW
      PRINT 6726,TFD,TFWD
      PRINT 6735,DATD,DATWD
      PRINT 6737,CIMD,CIMW
      PRINT 6739,CIGW
      PRINT 6742,XOTHD,XOTHWD
      PRINT *," "
      PRINT 6755,TOTD,TOTWD
      PRINT *," "
      PRINT 6795,TW,TW+XY
 6795 FORMAT(*AVG.MTBFS: 0 TO *,F4.1,F6.1,* TO *F4.1,*  TOTAL*)
      PRINT 6797,GW,GDFW,GWD
 6797 FORMAT(9X,F9.1,3X,F9.1,1X,F9.1)
 6800 CONTINUE
 8000 CONTINUE
 8010 PRINT *,"INPUT CODE"
      READ *,KFLAG
      IF(KFLAG.GE.99) GO TO 9999
      IF(KFLAG.LT.0) GO TO 50
      IF(KFLAG.EQ.0) GO TO 1001
      GO TO (8030,8050,8080,8090,8100,8110,8115,8120,8130
+      ,8140,8150,8160,8170,8180,8190,8200,8210,8220
+     ,8230,8240,8260,8290,8300,8310,8320,8330,8340) KFLAG
*          K=1
 8030 PRINT *,"INPUT FILE-1 NAME IN QUOTES"
      IUN=IPW=ICT=IUCW=ITEST=0
      IFUNC=3HGET $ LFN1=5HTAPE1 $ LFN2=5HTAPE2
      READ *,IPFN1
 8033 FORMAT(A5)
      CALL PFSUB(IFUNC,LFN1,IPFN1,IUN,IPW,ICT,0,IUCW,ITEST,ERRMSG)
      PRINT *,"INPUT FILE-2 NAME IN QUOTES"
      READ *,IPFN2
      CALL PFSUB(IFUNC,LFN2,IPFN2,IUN,IPW,ICT,0,IUCW,ITEST,ERRMSG)
      KFLAG = 0
      GO TO 45
*          K=2
 8050 PRINT *,"MTBF FACTOR & RETEST OK RATES(RTOKS,RTOKM)"
      PRINT *,VFACM,RTOKS,RTOKM
      READ *,VFAC,RTOKS,RTOKM
      VFACM = VFACM*VFAC
      DO 8068 J=1,NLRU
      YTF(J)=VFAC*YTF(J)
      NM=NMOD(J)
      IF(NM.LE.0) GO TO 8068
      DO 8066 I=1,NM
      XBF(I,J)=VFAC*XBF(I,J)
 8066 CONTINUE
 8068 CONTINUE
      SMTBF = VFAC*SMTBF
      GO TO 8000
*          K=3
 8080 CONTINUE
      PRINT *,"PNRTSSD,PNRTSSW,PNRTSMD,PNRTSMW"
      PRINT *, PNRTSSD,PNRTSSW,PNRTSMD,PNRTSMW
      READ *, PNRTSSD,PNRTSSW,PNRTSMD,PNRTSMW
      GO TO 8000
*          K=4
 8090 CONTINUE
```

(continued)

Figure A-9. (continued)

```
13330 PRINT *,"RIO,RIM"
13340 PRINT *, RIO,RIM
13350 READ *, RIO,RIM
13360 GO TO 8000
13370*      K=5
13380 8100 CONTINUE
13390 PRINT *,"ROIO,ROIM,ROMO,ROMM"
13400 PRINT *, ROIO,ROIM,ROMO,ROMM
13410 READ *,ROIO,ROIM,ROMO,ROMM
13420 GO TO 8000
13430*      K=6
13440 8110 CONTINUE
13450 PRINT *,"TBRCO,TBRCM,TOII,TOIM"
13460 PRINT *, TBRCO,TBRCM,TOII,TOIM
13470 READ *, TBRCO,TBRCM,TOII,TOIM
13480 GO TO 8000
13490*      K=7
13500 8115 CONTINUE
13510 PRINT *,"TDRCIO,TDRCIM,TDRCMO,TDRCMM"
13520 PRINT *, TDRCIO,TDRCIM,TDRCMO,TDRCMM
13540 READ *, TDRCIO,TDRCIM,TDRCMO,TDRCMM
13550 ??=M
13560 GO TO 8000
13570*      K=8
13580 8120 CONTINUE
13590 PRINT *,"EMORT,VMOD,RIUFF"
13600 PRINT *, EMORT,VMOD,RIUFF
13610 READ *, EMORT,VMOD,RIUFF
13620 GO TO 8000
13630*      K=9
13640 8130 CONTINUE
13650 PRINT *,"CALRCM(1),CALRCM(2),CALRCM(3)"
13660 PRINT *, CALRCM(1),CALRCM(2),CALRCM(3)
13670 READ *, CALRCM(1),CALRCM(2),CALRCM(3)
13680 GO TO 8000
13690       K=10
13700 8140 CONTINUE
13710 PRINT *,"AALRCM(1),AALRCM(2),AALRCM(3)"
13720 PRINT *, AALRCM(1),AALRCM(2),AALRCM(3)
13730 READ *, AALRCM(1),AALRCM(2),AALRCM(3)
13740 GO TO 8000
13750       K=11
13760 8150 CONTINUE
13770 PRINT *,"CCMML(1),CCMML(2),CCMML(3)"
13780 PRINT *, CCMML(1),CCMML(2),CCMML(3)
13790 READ *, CCMML(1),CCMML(2),CCMML(3)
13800 GO TO 2000
13810*      K=12
13820 8160 CONTINUE
13830 PRINT *,"ACMMLO(1),ACMMLO(2),ACMMLO(3)"
13840 PRINT *, ACMMLO(1),ACMMLO(2),ACMMLO(3)
13850 READ *, ACMMLO(1),ACMMLO(2),ACMMLO(3)
13860 GO TO 8000
13870*      K=13
13880 8170 CONTINUE
13890 PRINT *,"ACMMLW(1),ACMMLW(2)"
13900 PRINT *, ACMMLW(1),ACMMLW(2)
13910 READ *, ACMMLW(1),ACMMLW(2)
13920 GO TO 8000
13930*      K=14
13940 8180 CONTINUE
13950 PRINT *,"CCMMM(1),CCMMM(2),CCMMM(3)"
```

(continued)

Figure A-9. (continued)

```
13960 PRINT ◆, CCMMM(1),CCMMM(2),CCMMM(3)
13970 READ ◆, CCMMM(1),CCMMM(2),CCMMM(3)
13980 GO TO 8000
13990◆      K=15
14000 8190 CONTINUE
14010 PRINT ◆,"ACMMMO(1),ACMMMO(2),ACMMMO(3)"
14020 PRINT ◆, ACMMMO(1),ACMMMO(2),ACMMMO(3)
14030 READ ◆, ACMMMO(1),ACMMMG(2),ACMMMO(3)
14040 GO TO 8000
14050◆      K=16
14060 8200 CONTINUE
14070 PRINT ◆,"ACMMMW(1),ACMMMW(2)"
14080 PRINT ◆, ACMMMW(1),ACMMMW(2)
14090 READ ◆, ACMMMW(1),ACMMMW(2)
14110 GO TO 8000
14120◆      K=17
14130 8210 CONTINUE
14140 PRINT ◆,"CALFFM(1),CALFFM(2),CALFFM(3)"
14150 PRINT ◆, CALFFM(1),CALFFM(2),CALFFM(3)
14160 READ ◆, CALFFM(1),CALFFM(2),CALFFM(3)
14170 GO TO 8000
14180◆      K=18
14190 8220 CONTINUE
14200 PRINT ◆,"AALFFM(1),AALFFM(2),AALFFM(3)"
14210 PRINT ◆, AALFFM(1),AALFFM(2),AALFFM(3)
14220 READ ◆, AALFFM(1),AALFFM(2),AALFFM(3)
14230 GO TO 8000
14240◆      K=19
14250 8230 CONTINUE
14260 PRINT ◆,"FMFD(1),FMFD(2),FMFD(3)"
14270 PRINT ◆, FMFD(1),FMFD(2),FMFD(3)
14280 READ ◆, FMFD(1),FMFD(2),FMFD(3)
14290 GO TO 8000
14300◆      K=20
14310 8240 CONTINUE
14320 PRINT ◆,"FMFW(1),FMFW(2),FMFW(3)"
14330 PRINT ◆, FMFW(1),FMFW(2),FMFW(3)
14340 READ ◆, FMFW(1),FMFW(2),FMFW(3)
14350 GO TO 8000
14360◆      K=21
14370 8260 CONTINUE
14380 PRINT ◆,"FIK,FFT,DWF,DTF,FIWFF,YCOTHW"
14390 PRINT ◆, FIK,FFT,DWF,DTF,FIWFF,YCOTHW
14400 READ ◆, FIK,FFT,DWF,DTF,FIWFF,YCOTHW
14410 GO TO 8000
14420◆      K=22
14430 8290 CONTINUE
14440 PRINT ◆,"NFCD,NFCW,CIM"
14450 PRINT ◆, NFCD,NFCW,CIM
14460 READ ◆, NFCD,NFCW,CIM
14470 GO TO 8000
14480C      K=23
14490 8300 CONTINUE
14500 PRINT ◆,"OTHO,OTHW,OTHWC,YCTHO,CTRANS"
14510 PRINT ◆, OTHO,OTHW,OTHWC,YOTHO,CTRANS
14520 READ ◆, OTHO,OTHW,OTHWO,YOTHO,CTRANS
14530 GO TO 8000
14540C      K=24
14550 8310 CONTINUE
14560 PRINT ◆,"GLET,TG"
14570 PRINT ◆, GLET,TG
```

(continued)

Figure A-9. (continued)

```
14580 READ *, SIST,TG
14590 GO TO 8000
14600 9320 CONTINUE
14610C      K=25
14620 PRINT *,"PCTGM,PCTGD,PLIM"
14630 PRINT *, PCTGM,PCTGD,PLIM
14640 READ *, PCTGM,PCTGD,PLIM
14650 GO TO 8000
14660 9330 CONTINUE
14670C      K=26
14680 PRINT *,"RSUFF,NY,DR,NMC"
14690 PRINT *, RSUFF,NY,DR,NMC
14700 READ *, RSUFF,NY,DR,NMC
14710 GO TO 8000
14711 9340 CONTINUE
14712C      KFLAG = 27
14713 PRINT *,"TGSID,TGSIW,TGSMD,TGSMW"
14714 PRINT *, TGSID,TGSIW,TGSMD,TGSMW
14715 READ *,TGSID,TGSIW,TGSMD,TGSMW
14716 GO TO 8000
14720 9999 STOP$END
14730 SUBROUTINE NSRRB(N,GF,INCIB,L,LI,LF)
14740C THIS SUBROUTINE FINDS THE YEAR WITH THE MAXIMUM DEMAND RATE AT THE
14750C BASE
14760C  N - YEAR WITH MAXIMUM DEMAND RATE
14770C  GF - GROWTH FACTOR
14780C  NCIB - CUMULATIVE # OF ACTIVATED BASES PER YEAR PER BASE TYPE
14790C  L - BASE TYPE OF INTEREST
14800C  LI - STARTING YEAR OF INTEREST
14810C  LF - FINAL YEAR  OF INTEREST
14820 DIMENSION GF(1), INCIB(21,5)
14830 MAX = -1.
14840C      SET UP DO LOOP
14850 DO 200 II=LI,LF
14855 IIP1 = II + 1
14860 R = (INCIB(II,L) + INCIB(IIP1,L))*.5
14865 IF(R .LT. .01) GO TO 200
14870 TEST = R/GF(II)
14880 IF(TEST .LT. MAX) GO TO 200
14890 MAX = TEST
14900 N=II
14910 200 CONTINUE
14920 RETURN
14930 END
14940 SUBROUTINE NSRRD(N,GF,NCIY,LI,LF)
14950C THIS SUBROUTINE FINDS THE YEAR WITH THE MAXIMUM DEMAND RATE
14960C AT THE DEPOT
14970C  N - YEAR OF MAXIMUM DEMAND RATE
14980C  GF - GROWTH FACTOR
14990C  NCIY - CUMULATIVE NUMBER OF ACTIVATED BASES PER YEAR
15000C  LI - STARTING YEAR OF INTEREST
15010C  LF - FINAL YEAR OF INTEREST
15020 DIMENSION GF(1), NCIY(1)
15030 MAX = -1.
15040C    SET UP DO LOOP
15050 DO 200 II=LI,LF
15055 IIP1 = II + 1
15060 R = NCIY(II) + NCIY(IIP1)
15065 R = R*.5
15070 TEST = R/GF(II)
15080 IF(TEST .LT. MAX) GO TO 200
```

(continued)

Figure A-9. (continued)

```
15090 MAS = TEST
15100 N=I
15110 200 CONTINUE
15120 RETURN
15130 END
15140 FUNCTION SF(T1,T2,TI,TL,B)
15150C  THIS FUNCTION IS THE DUANE MODEL CUMULATIVE MTBF GROWTH FACTOR
15160C  FOR THE PERIODS OF ORGANIC AND WARRANTY.  THE GROWTH FACTOR,SF,
15170C  IS COMPUTED SUCH THAT THE CUMULATIVE MTBF OVER (T1,T2) IS SF*THI.
15180C  WHERE THI IS A REFERENCED VALUE OF THETA AT TIME TI.
15190 BM = -B
15200 BM1 = 1. - B
15210 RTI = TI**BM
15220C SEE IF MTBF HAS REACHED SATURATION
15230 IF(T2 .LE. TL) GOTO 10138
15240C SEE IF SATURATION LEVEL OCCURS WITHIN INTERVAL (T1,T2)
15250 IF(T1 .LT. TL) GO TO 10128
15260C  COMPUTE CUMULATIVE GROWTH FOR SATURATION
15270 TDEN = (T2-T1)*(TL**B)
15280 GO TO 10144
15290 10128 CONTINUE
15300C  COMPUTE CUMULATIVE GROWTH FOR CASE WHEN T1   TL    T2
15310 TINT = (TL**BM1 - T1**BM1)/BM1
15320 TDEN = TINT + (T2-TL)*(TL**B)
15330 GO TO 10144
15340 10138 CONTINUE
15350C  COMPUTE CUMULATIVE GROWTH WITH NO SATURATION
15360 TDEN = (T2**BM1-T1**BM1)/BM1
15370 10144 CONTINUE
15380C  COMPLETE FINAL COMPUTATION
15390 SF = (T2-T1)*RTI/TDEN
15400 RETURN
15410 END
15420 FUNCTION SFWO(T1,T2,TI,TWH,TL,FLIM,BO,BW)
15430C  THIS FUNCTION IS THE DUANE MODEL CUMULATIVE MTBF GROWTH FACTOR
15440C  FOR THE PERIOD AFTER WARRANTY.  THE GROWTH FACTOR,SFWO, IS
15450C  COMPUTED SIMILAR TO SF BUT HAS THE ADDITIONAL PARAMETER TWH WHICH
15460C  IS THE OPERATING HOURS AT TRANSITION.
15470 BOM = -BO
15480 BOM1 = 1. - BO
15490 BWM = -BW
15500 BWMBO = BW - BO
15510 TWBW = TWH**BWMBO
15520 IF(BO .GT. 0.) GO TO 14758
15530 BOR = 0.
15540 GO TO 14762
15550 14758 CONTINUE
15560 BOR = 1./BO
15570 14762 CONTINUE
15580 RTIW = TI**BWM
15590C  SEE IF MTBF HAS SATURATED
15600 IF(T1 .GT. TL) GO TO 10366
15610C  FIND TIME AT WHICH SATURATION OCCURS AFTER TRANSITION
15620 TARG = (1.+FLIM)/(TWBW*RTIW)
15630 TWOL = TARG**BOR
15640C  SEE IF SATURATION LEVEL OCCURS WITHIN INTERVAL (T1,T2)
15650 IF(T2 .GT. TWOL) GOTO 10356
15660C  COMPUTE CUMULATIVE GROWTH WITH NO SATURATION
15670 TDEN = (T2**BOM1-T1**BOM1)/BOM1
15680 GO TO 10374
15690 10356 CONTINUE
15700C  COMPUTE CUMULATIVE GROWTH WITH SATURATION
```

(continued)

Figure A-4. (continued)

```
TDEN = (TWOL**BOM1-T1**BOM1)/BOM1
+ +  (T2-TWOL)*(TWOL**BO)
GO TO 10574
10566 CONTINUE
C  COMPUTE CUMULATIVE GROWTH FOR FULL SATURATION AND RETURN
SFWO = RTIW*(TL**BW)
RETURN
10574 CONTINUE
C  COMPLETE CALCULATION OF CUMULATIVE GROWTH
SFWO = (T2-T1)*TWBW*RTIW*TDEN
RETURN
END
FUNCTION SFLC(T1,T2,TI,TWH,TL,FLIM,BO,BW)
C  THIS FUNCTION IS THE DUANE MODEL CUMULATIVE MTBF GROWTH FACTOR
C  FOR THE ENTIRE LIFE CYCLE.  THIS FUNCTION ESSENTIALLY COMBINES
C  THE GROWTH FUNCTIONS OF SF AND SFWO.
BOM1 = 1. - BO
BWM = -BW
BWM1 = 1.-BW
BWMBO = BW - BO
BOMBW = -BWMBO
IF(BO .GT. 0.) GO TO 15108
BOR = 0.
GO TO 15112
15108 CONTINUE
BOR = 1./BO
15112 CONTINUE
TWBW = TWH**BWMBO
TWBO = TWH**BOMBW
RTIW = TI**BWM
C  SEE IF MTBF SATURATION OCCURS BEFORE TRANSITION
IF(TL .GT. TWH) GO TO 10540
C  COMPUTE CUMULATIVE GROWTH WITH FULL SATURATION & RETURN
SFLC = SF(T1,T2,TI,TL,BW)
RETURN
10540 CONTINUE
C  COMPUTE CUMULATIVE DEMANDS OVER WARRANTY PERIOD
TWINT = (TWH**BWM1 - T1**BWM1)/BWM1
C  FIND TIME AT WHICH SATURATION OCCURS AFTER TRANSITION
TARG = (1.+ FLIM)/(TWBW*RTIW)
TWOL = TARG**BOR
C  SEE IF SATURATION LEVEL OCCURS AFTER PERIOD(T1,T2)
IF(TWOL .GT. T2) GO TO 10564
C  COMPUTE CUMULATIVE GROWTH FOR  T1  TL  T2
TWOINT =TWBO*(TWOL**BOM1 - TWH**BOM1)/BOM1
+ +  TWBO*(T2-TWOL)*(TWOL**BO)
GO TO 10570
10564 CONTINUE
C  COMPUTE CUMULATIVE GROWTH WITH NO SATURATION
TWOINT = TWBO*(T2**BOM1-TWH**BOM1)/BOM1
10570 CONTINUE
C  COMPLETE CALCULATION OF CUMULATIVE GROWTH
SFLC = (T2-T1)*RTIW*(TWINT + TWOINT)
RETURN
END
SUBROUTINE SPARE(J,ISPT,IDS,RRPTOK,DRTOK,DRTL,TOSS,TOSM,RNRTSS,RNRTSM,
+RSUFF,DSRU,H,NB,RMTBD,TIME,SPARES)
C
C  THIS SUBROUTINE CALCULATES THE BASE AND DEPOT SPARES SIMULTANEOUSLY
C  BY EMPLOYING AN APPROXIMATION TO THE MOD METRIC TECHNIQUE.
C
REAL N,NNEW,NB
```

(continued)

Figure A-9. (continued)

```
 DIMENSION ISPA(5)
C GABPT = AVERAGE BASE PIPELINE TIME FOR GUARANTEED MTBF (UBS)
C IBS = BASE STOCK QUANTITY
C EBO(DS,DRT,IDS) = EXPECTED BACKORDERS
C DDL = DEPOT DEMAND RATE
C DRT = DEPOT REPAIR CYCLE TIME MINUS BASE CYCLE TIME
C IDS,IS = DEPOT SPARES LEVEL
C BRRTOK = RTOK RATE FOR BASE
C DRTOK = TIME TO PROCESS RTOK AT BASE
C DRTL = DEPOT REPAIR CYCLE TIME
C TOSS = ORDER AND SHIP TIME ASSOCIATED WITH CENTRAL SUPPLY TO
C REPLENISH BASE WITH LRU
C TOSM = ORDER AND SHIP TIME ASSOCIATED WITH CENTRAL SUPPLY TO
C REPLENISH BASE WITH SRU
C TILRU = INCREMENT TIME DUE TO NONAVAILABILITY OF LRU AT DEPOT
C TISRU = INCREMENT TIME DUE TO NONAVAILABILITY OF SRU AT DEPOT
C ABPTL = AVERAGE BASE PIPELINE TIME FOR LRU AT BASE WITH SRU
C REPLACEABLE STOCK AT BASE
C ABPTS = AVERAGE PIPELINE TIME ASSOCIATED WITH REPLENISHING
C AN SRU AT BASE
C PNRTS = NRTS RATE
C PRTS = PROBABILITY OF REPAIR THIS STATION
C PSRU = PROBABILITY OF HAVING AN SRU AT BASE
C PNSRU = PROBABILITY OF NOT HAVING AN SRU AT BASE
C DSRU = DAYS TO REPLACE AN SRU IN A LRU AT BASE
C ALPHA = DEMAND RATE FOR UNITS AT BASE
C N,NB = NUMBER OF INSTALLS PER BASE
C H = OPERATE HOURS PER DAY PER AIRCRAFT
C ISP = NUMBER OF SPARES PER BASE
C ISPT = TOTAL SPARES(ALL BASES AND DEPOT IF SAME TYPE OF SPARE)
C PMTBD = MEAN TIME BETWEEN DEMAND FOR LRU
C PSUPP = PROBABILITY THAT A SPARE IS AVAILABLE
C
C J = FLAG FOR TYPE OF SPARING
C      1--LRU SPARING AT BASE, NO REPLACEABLE SRUS AT BASE
C      2--LRU SPARING AT BASE WITH REPLACEABLE SRUS AT BASE
C      3--SRU SPARING AT BASE
C
C INITIALIZATION
C
 PSRU = PSUPP
 PN = N $ PNB = NB
 PRTSS = 1.0 - PNRTSS - BRRTOK
 PNSRU = 1.0 - PSRU
 ALPHA= PNB*H/PMTBD
 PRTSM = 1.0 - PNRTSM - BRRTOK
 DDLS = ALPHA*PNRTSS
 DDLM = ALPHA*PNRTSM
 DRT = DRTL - DSRU
 IDS = 0
 SPARES = 0.0
C
 IDSINC = 1
 TISRU = TINC
 TILRU = 0.0
C       INITIALIZATION FOR RUNNING AVERAGE
 MOD = 5
 MODM1 = MOD - 1
 ISPAVG = 0
 ISPMIN = 1000000
 DO 6232 II = 1,MODM1
 ISPA(II) = ISPMIN
```

(continued)

Figure A-9. (continued)

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```
ISPAVG = ISPAVG + ISPA(I)
6232 CONTINUE
IAVGC = MOCM1
C
C   BASIC LOOP
C
6450 IDS = IDS + IDSINC
C
C CALCULATE PIPELINE TIMES
GO TO(6530,6570,6640),L
C     CALCULATE GARPT
C
6530 CONTINUE
6535 TILRU = EBO(DDLS,DRT,IDS)/DDLS
TIME = BRRTOK*DRTOK + (1.0-BRRTOK)*(DSRU+TOSS+TILRU)
GO TO 6700
C    CALCULATE ABRTL
C
6570 CONTINUE
TILRU = EBO(DDLS,DRT,IDS)/DDLS
TIME = BRRTOK*DRTOK + RNRTSS*(TOSS + DRTL + TILRU) +
+           RRTSS*(RSRU*DSRU + RNSRU*(TOSM + TISRU + DSRU))
GO TO 6700
C
C  CALCULATE PIPELINE TIME FOR MODULES
C
6640 DRT = DRTL - DSRU
6642 TISRU = EBO(DDLM,DRT,IDS)/DDLM
TIME =((TOSM +DSRU + TISRU)*RNRTSM + RRTSM*DSRU + BRRTOK*DRTOK
C
6700 CONTINUE
C    CALCULATE SPARES
C
IF(IDS .GT. 1) GO TO 6800
C CHECK FOR FRACTIONAL DEMANDS
CHECK = TIME*ALPHA
IF(CHECK .GT. 1.5) GO TO 6800
C     COMPUTE FRACTIONAL SPARES
SPARES = CHECK + 1.0
ISPT = 0
TINC = 0.0
C EXIT SPARES ROUTINE WITH FRACTIONAL SPARES CALCULATION
RETURN
6800 CONTINUE
C
C CALCULATE SPARES AT BASE AND DEPOT
7060 ISP= ISPARE(ALPHA,TIME,PSUFF)
ISPT = ISP +IDS
C
7100 CONTINUE
C
C CHECK FOR MINIMUM NUMBER OF SPARES
C
C     STORE MINIMUM NUMBER OF TOTAL SPARES
IF(ISPMIN .LT. ISPT) GO TO 7222
ISPMIN = ISPT
IDSM = IDS
TINC = TISRU $ IF(J .EQ. 1) TINC = TILRU
7222 CONTINUE
PTINC=TISRU $ IF(J .EQ.1)PTINC = TILRU
C CHECK FOR MAXIMUM NUMBER OF DEPOT SPARES ALLOWED
C      INCREMENT POINTERS
```

(continued)

Figure A-9. (continued)

```
      IAVGC = IAVGC +1
      IAVGC = MODZEB(IAVGC,MOC)
      IAVGD = IAVGC +1
      IAVGD = MODZEB(IAVGD,MOC)
C     COMPARE COMPUTED VALUE (IIRT) TO RUNNING AVERAGE (IIRAVG)
      ITEST = MOCM1*IIRT - MOCM1
C     PRINT 7246,IDS,IIRT,IIR,IIRAVG,ITEST,RTINC
      IF(ITEST .GT. IIRAVG) GO TO 7255
C     UPDATE RUNNING AVERAGE
      IIRA(IAVGC) = IIRT
      IIRAVG = IIRAVG + IIRT - IIRA(IAVGD)
 7246 FORMAT(T2,"IDS=",I4,T12,"IIRT=",I4,T24,"IIR=",I4,
     +  T34,"IIRAVG=",I7,T50,"ITEST=",I7,T65,"TINC=",F8.2)
      GO TO 6450
 7255 IIRT = IIRMIN $ IDS = IDIM
 7260 RETURN
      END
      FUNCTION EBO(DD,DRT,IDS)
C     CALCULATION OF INCREMENT TIME DUE TO NONAVAILABILITY OF ITEM
C
      DDRT = DD*DRT
      IDDRT = DDRT/10.
      EDRT = (EXP(-IDDRT))**10.
      DS = IDS
      RIIF = 1.0
      SUML = DS*EDRT
      S = 1.0
C     START SUMMATION PROCESS
      DO 8100 II=1,IDS
      RII = II
      S = S*DDRT/RII
      SUM = S*EDRT*(DS-RII)
      SUML = SUM + SUML
 8100 CONTINUE
      EBO = DDRT - DS + SUML
      RETURN
      END
      FUNCTION ISPARE(A,T,R)
C     CALCULATION OF SPARES ROUTINE
C     INITIALIZE
      RIIF = 1.0
      AT = A*T
      EAT = EXP(-AT)
      S=EAT
      SUM = EAT
      II = 0
C     START SUMMATION PROCESS
C
 8280 II = II + 1
      RII = II
C
      S = S*AT/RII
      SUM = SUM + S
      TEST = SUM - R
      IF(TEST) 8280,8370,8370
 8370 ISPARE = II
      RETURN
      END
      FUNCTION MODZEB(MD,MOC)
C     THIS IS A MODULO ROUTINE FOR INTEGERS
 8405 IF(MD .LE. MOC) GO TO 8415
      MD =MD - MOC
```

(continued)

Figure A-9. (continued)

```
18180 GO TO 8405
18190 8415 MODZEB = MO
18200 RETURN
18210 END
```

Figure A-9. (continued)

APPENDIX B

MTBF GROWTH MODEL

1. INTRODUCTION

Equipment reliability is one of the significant factors in evaluating the economic aspect of warranty. This appendix describes the approach to employing a modified form of the Duane Model for computing the mean time between failures (MTBF) under organic and warranty support.

2. MTBF GROWTH PERIODS

During the useful life of an equipment, there are several periods of interest. The first is the warranty period, i.e., the time from zero to the time of transition, TW, in years. The second period is the remainder of the life cycle following transition from warranty to organic, designated TW, NY, where NY is the number of years in the life cycle. A third period of interest is the entire life cycle O, NY.

For each period of interest an MTBF growth function is required. The computer model must be flexible enough to accommodate the different forms of growth and to provide smooth transition from one period of interest to the other.

3. REASON FOR DUANE MODEL

Numerous MTBF growth models exist, including the ARINC Research Model*, the IBM Model**, the Exponential-Power Series Model**, the Aerof Model**, and the Lloyd-Lipow Model**. All of these models, including the Duane Model, are well recognized in industry.

---

*H. Balaban and B. Retterer, *Guidelines for Application of Warranties to Air Force Electronic Systems*, ARINC Research Publication 1500-01-1-1451, December 1975 and RADC Report TR-76-32. (A023956)

**R. Schafer, et al., *Reliability Growth Study*, Hughes Aircraft Company, RADC Report 75-253, October 1975. (A023926)

Some models are more complicated than others, requiring many more inputs than the simpler models such as the Duane Model. However, the simpler models usually have no upper limit and grow without bound. A compromise between simplicity and unbounded growth is to choose a simple model and impose an upper limit on this model. After surveying the advantages and disadvantages of several models for this analysis, we decided to modify the simple Duane Model by imposing an upper limit of growth.

4. DUANE GROWTH MODEL

In 1962 Duane observed that the logarithm of observed cumulative MTBF was a linear function of time*

$$\ln \Theta(O,T) = a + \beta \ln T$$

where $\Theta(O,T)$ is the cumulative MTBF over the observation period, (O,T). The measure of interest in the life-cycle cost analysis is the average MTBF over an observed period, (T_1,T_2). This measure can be found from the definition of cumulative MTBF

$$\Theta\ (T_1,T_2) = \frac{T_2 - T_1}{\int_{T_1}^{T_2} \frac{d\lambda}{\theta(\lambda)}}$$

where

$\Theta(T_1,T_2)$ = the cumulative MTBF over the period T_1,T_2

$\theta(T)$ = the instantaneous MTBF at time T

T_1 = the time at the beginning of the interval of interest

T_2 = the time at the end of the interval of interest

The requirement is to find the instantaneous MTBF and then integrate it over the interval of interest. This instantaneous MTBF is equal to

$$\theta(T) = A\ T^{\beta}/(1 - \beta)$$

which can be rewritten

$$\theta(T) = \theta(T_I)\ T^{\beta}\ (T_I)^{-\beta}$$

where $\theta(T_I)$ is the instantaneous value of MTBF at time T_I.

---

*J. T. Duane, "Learning Curve Approach to Reliability Monitoring," *IEEE Transactions on Aerospace*, 1964, Vol. 2, pp. 563-566.

5. MODIFIED DUANE MODEL

Although the Duane model is simple, it has unlimited growth, which is uncharacteristic of real-life situations. To alleviate this problem, an upper limit was placed on the model as follows:

$$\theta(T) = \begin{cases} (T_I)^{-\beta}\, \theta(T_I)\, T^{\beta} & T \leq T_L \\ \theta_L & T \geq T_L \end{cases}$$

where T_L is the time at which the upper limit, θ_L, is attained. Thus $\theta(T)$ can be described by two straight lines as depicted in Figure B-1.

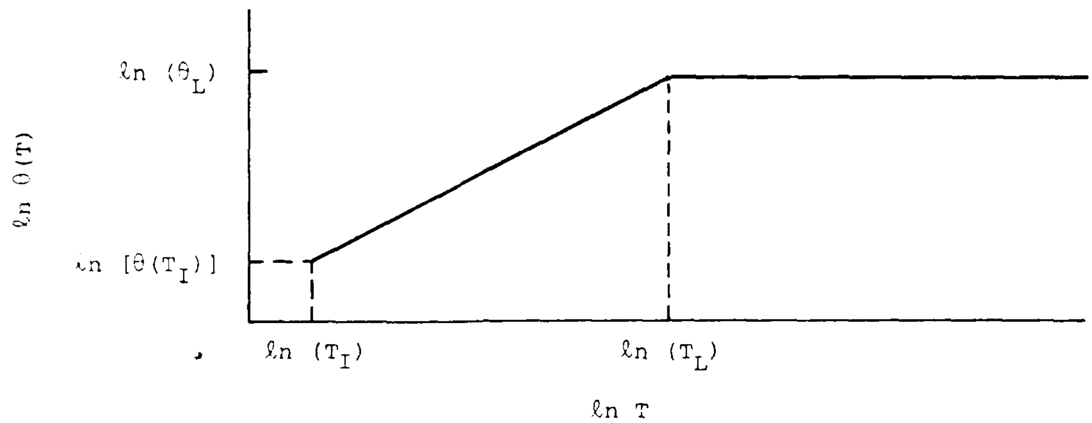

Figure B-1. MODIFIED INSTANTANEOUS MTBF DUANE MODEL

6. SPECIFICATION OF MODIFIED DUANE MODEL

The instantaneous MTBF function described in Section 5 is graphically represented by two intersecting straight lines. To describe each line, all that is required is a y intercept and a slope. For the horizontal line, the slope is zero and the y intercept is $\ln(\theta_L)$. For $T \leq T_L$, the slope is β. Since y intercept is $\ln T = 0$, ($T = 1$ hour), a more appropriate time of T_I is used when an initial instantaneous value of MTBF is known, i.e., $\theta(T_I)$.

In the economic model, it was assumed that all units (subassemblies and modules) have the same growth rates. That is, all units will have the same β factor in the Modified Duane Model for a given support (warranty or organic) over a given period of interest. Thus, if a growth function can be determined so that

$$\theta(T_1, T_2) = F(T_1, T_2)\, \theta(T_1)$$

then for any given time, the growth function should only be computed once instead of computing the MTBFs for every subassembly and module.

7. GROWTH FUNCTIONS FOR EACH PERIOD OF INTEREST

To utilize the MTBF growth model in the LCC model, the instantaneous and cumulative MTBFs must be specified over the following periods of interest:

- Warranty period (O,TW)
- Full organic period (O,NY)
- Organic after transition (TW,NY)
- Full life-cycle-cost period (O,NY) including warranty and organic after transition

First, the instantaneous MTBF must be specified, and then this form must be integrated to obtain the cumulative MTBFs. The following subsections present the development of the instantaneous and cumulative MTBFs for each period of interest.

7.1 Warranty and Full Organic Periods

The cases of warranty or full organic periods are similar. The major difference is the growth rate (β) itself. At this time, a label convention of W for warranty and O for organic will be adopted. Therefore, the form of $\theta(T)$ for warranty and full organic is as follows

$$\theta_O(T) = \begin{Bmatrix} (T_I)^{-\beta_O}\,\theta(T_I)\;(T)^{\beta_O} & T \leq T_{OL} \\ \theta_L & T \geq T_{OL} \end{Bmatrix}$$

$$\theta_W(T) = \begin{Bmatrix} (T_I)^{-\beta_W}\,\theta(T_I)\;(T)^{\beta_W} & T \leq T_{WL} \\ \theta_L & T \geq T_{WL} \end{Bmatrix}$$

where

$\theta_O(T)$ = the MTBF for organic support over the interval (O,NY)

$\theta_W(T)$ = the MTBF for warranty support over the interval (O,T_W)

θ_L = the upper limit of MTBF for both warranty and organic support

T_{OL} = the time at which the MTBF reaches θ_L under organic support

T_{WL} = the time at which the MTBF reaches θ_L under warranty support

Note that a restriction has been made that the upper limit of MTBF is the same, whether under organic or warranty. The major differences in the

growth curves are the growth rates, β_O and β_W. For simplicity, the MTBF for organic and warranty have been assumed to be equal at time T_I, as illustrated in Figure B-2.

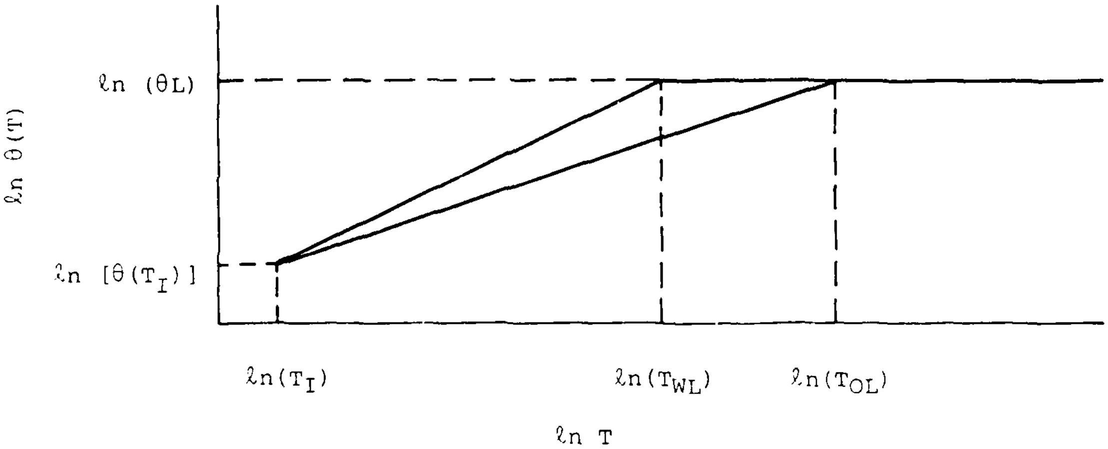

Figure B-2. MTBF GROWTH CURVES FOR FULL ORGANIC AND WARRANTY SUPPORT

With these formulations *for $\theta(T)$, the cumulative* MTBF growth functions between time T_1 and T_2 can be found as follows

$$\theta(T_1,T_2) = \frac{T_2 - T_1}{\int_{T_1}^{T_2} \frac{d\lambda}{\theta(\lambda)}}$$

Since the warranty and full organic have the same formulation, the labeled subscripts have been deleted.

To find the cumulative MTBF, the above integral must be evaluated. Note that the MTBF may have been saturated before T_2. Thus two cases must be considered. The first case is when saturation occurs before T_2. The integral must be evaluated as follows

$$\int_{T_1}^{T_2} \frac{d\lambda}{\theta(\lambda)} = \frac{1}{\theta(T_I)(T_I)^{-\beta}} \int_{T_1}^{T_L} \lambda^{-\beta} d\lambda + \int_{T_L}^{T_2} \frac{d\lambda}{L}$$

$$= \frac{(T_L)^{(1-\beta)} - (T_1)^{(1-\beta)}}{(1-\beta)\ \theta(T_I)(T_I)^{-\beta}} + \frac{T_2 - T_L}{L}$$

but

$$\theta_L = (T_I)^{-\beta}\,\theta(T_I)\,(T_L)^{\beta}$$

Therefore, the cumulative MTBF is

$$\theta(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta}\,\theta(T_L)}{\left[(T_L)^{1-\beta} - (T_1)^{1-\beta}\right]/(1-\beta) + (T_2 - T_L)/(T_L)^{\beta}}$$

and the cumulative growth function, F, is as follows

$$F(T_1,T_2) = \frac{(T_2 - T_1)\;T_I^{\,-\beta}}{\left[(T_L)^{1-\beta} - (T_1)^{1-\beta}\right]/(1-\beta) + (T_2 - T_L)/(T_L)^{\beta}} \qquad \text{for } T_L \leqslant T_2$$

The second case is when no saturation occurs. From the above formulation, it can be seen that the growth function is

$$F(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta}}{\left[(T_2)^{1-\beta} - (T_1)^{1-\beta}\right]/(1-\beta)} \qquad \text{for } T_2 \leqslant T_L$$

7.2 Organic Maintenance After Transition Period

After transition, it has been assumed that the instantaneous MTBF will grow at the organic rate (β_O) starting with the value of MTBFs under warranty at the time of transition. Three possible cases are illustrated in Figures B-3, B-4, and B-5. Case 1 is when transition occurs before saturation but the MTBF saturates before T_2 which, for the LCC analysis, T_2 = NY. This case is shown in Figure B-3.

The formulation for the instantaneous MTBF growth after transition for Case 1 is

$$\theta_{WO}(T) = (T_W)^{-\beta_O}\,\theta_{WO}(T_W)\,(T)^{\beta_O}$$

but

$$\theta_{WO}(T_W) = \theta_W(T_W) = (T_I)^{-\beta_W}\,\theta(T_I)\,(T_W)^{\beta_W}$$

then

$$\theta_{WO}(T) = (T_W)^{\beta_W - \beta_O}\,(T_I)^{-\beta_W}\,(T)^{\beta_O}\,\theta(T_I)$$

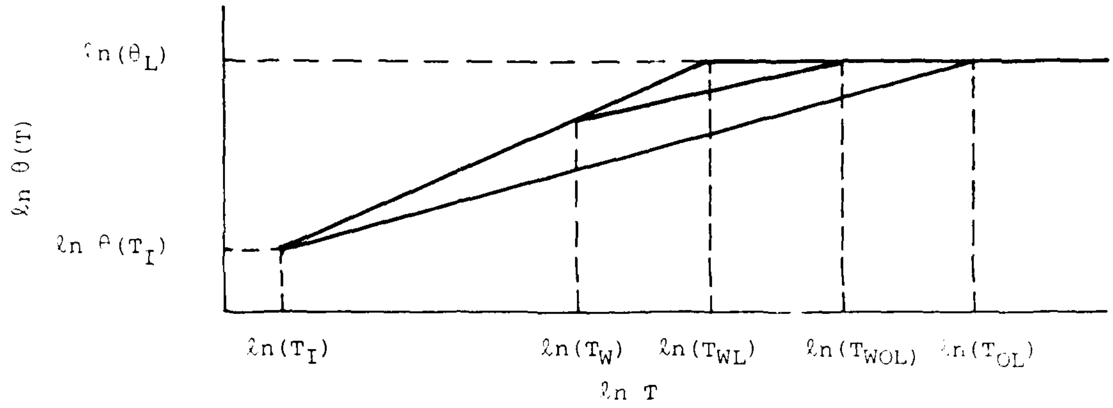

Figure B-3. INSTANTANEOUS MTBF GROWTH CURVES FOR WARRANTY, ORGANIC, AND POST-TRANSITION FOR CASE 1

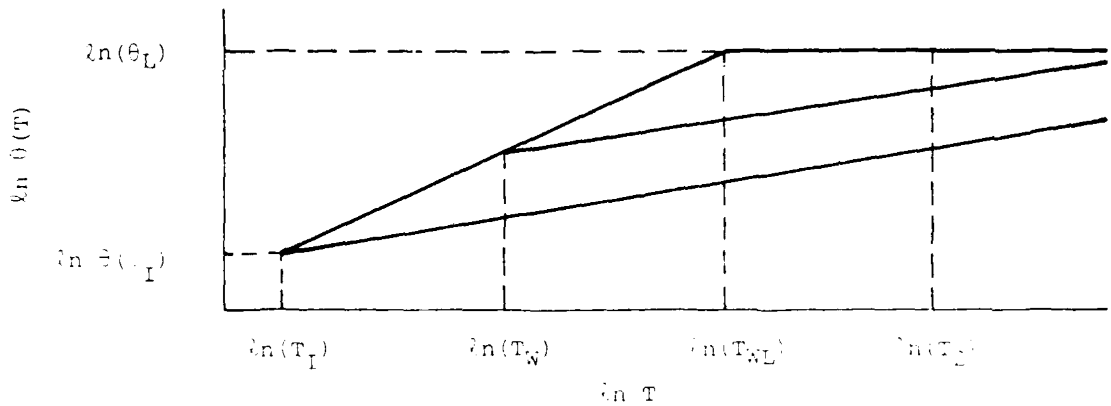

Figure B-4. INSTANTANEOUS MTBF GROWTH CURVES FOR WARRANTY, ORGANIC, AND POST-TRANSITION FOR CASE 2

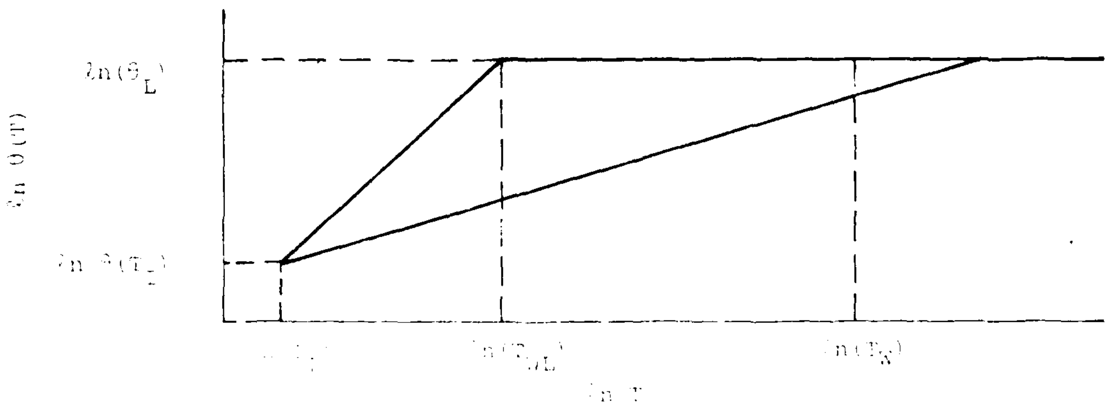

Figure B-5. INSTANTANEOUS MTBF GROWTH CURVES FOR WARRANTY, ORGANIC, AND POST-TRANSITION FOR CASE 3

As shown in Figure B-3, there is a new time, T_{WOL}, at which time the MTBF reaches its limit. This time can be found as follows

$$\theta_L = (T_W)^{\beta_W - \beta_O} (T_I)^{-\beta_W} (T_{WOL})^{\beta_O} \theta(T_I)$$

$$T_{WOL} = \frac{T_I}{T_W} \left[\left(\frac{\theta_L}{\theta(T_I)} \right) (T_W)^{\beta_O} \right]^{1/\beta_O}$$

With the formulation for $\theta_{WO}(T)$ and T_{WOL}, the cumulative MTBF can be found for the case in which $T_1 \leqslant T_{WOL} \leqslant T_2$.

$$\theta_{WO}(T_1,T_2) = \frac{T_2 - T_1}{\displaystyle\int_{T_1}^{T_{WOL}} \frac{d\lambda}{\theta_{WO}(2)} + (T_2 - T_{WOL})/\theta_L}$$

With the evaluation of the integral and some algebraic substitutions, the cumulative MTBF for the period after transition is

$$\theta_{WO}(T_1,T_2) = \frac{(T_2 - T_1)(T_W)^{\beta_W - \beta_O} (T_I)^{-\beta_W} \theta(T_I)}{\left[(T_{WOL})^{1-\beta_O} - (T_1)^{1-\beta_O} \right] / (1 - \beta_O) + (T_2 - T_{WOL})/(T_{WOL})^{\beta_O}}$$

and the cumulative growth function is

$$F_{WO}(T_1,T_2) = \frac{(T_2 - T_1)(T_W)^{\beta_W - \beta_O} (T_I)^{-\beta_W}}{\left[(T_{WOL})^{1-\beta_O} - (T_1)^{1-\beta_O} \right] / (1 - \beta_O) + (T_2 - T_{WOL})/(T_{WOL})^{\beta_O}}$$

for $T_1 \leqslant T_{WOL} \leqslant T_2$

Case 2 is when $T_{WOL} > T_2$, illustrated in Figure B-4.

The cumulative MTBF is

$$(T_1,T_2) = \frac{(T_2 - T_1)(T_W)^{\beta_W - \beta_O} (T_I)^{-\beta_W} \theta(T_I)}{\left[(T_2)^{1-\beta_O} - (T_1)^{1-\beta_O} \right] / (1 - \beta_O)}$$

and the growth function is

$$F_{WO}(T_1,T_2) = \frac{(T_2 - T_1)(T_W)^{\beta_W - \beta_O} (T_I)^{-\beta_W}}{\left[(T_2)^{1-\beta_O} - (T_1)^{1-\beta_O} \right] / (1 - \beta_O)}$$

Case [illegible] when [illegible] before [illegible], illustrated in Figure B-[illegible].

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WARRANTY-GUARANTEE APPLICATION GUIDELINES FOR AIR FORCE GROUND --ETC(U)
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UNCLASSIFIED 1710-01-1-1996 RADC-TR-79-287 NL

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For the situation in which $T_{WL} < T_W$, then the value of $\theta_{WO}(T) = \theta_L$ and the cumulative MTBF is

$$\Theta_{WO}(T_1,T_2) = \frac{(T_2 - T_1)}{(T_2 - T_1)/\theta_L}$$

$$= \theta_L$$

$$= (T_I)^{-\beta_W} (T_W)^{\beta_W} \theta(T_I)$$

and the growth function is

$$F_{WO}(T_1,T_2) = (T_I)^{-\beta_W} (T_{WL})^{\beta_W} \quad \text{for } T_{WL} < T_W$$

7.3 Life-Cycle Period

The final cumulative MTBF for the entire life cycle, which includes a warranty period, can be found by employing the $\theta(T)$s determined previously for the periods $(0,T_W)$ and (T_W,NY). The cumulative MTBF for the life cycle, Θ_{LC}, is

$$\Theta_{LC}(T_1,T_2) = \frac{T_2 - T_1}{\int_{T_1}^{T_W} \frac{d\tau}{\theta(\tau)} + \int_{T_W}^{T_L} \frac{d\tau}{\theta(\tau)}}$$

Depending at which point MTBF saturation occurs, the cumulative MTBF will be evaluated differently.

Case 1 is when the instantaneous MTBF reaches the upper limit before transition.

7.3.1 Case 1: $T_{WL} < T_W$

In Case 1, the MTBF reaches the upper limit before transition and thus $\theta(T)$ is

$$\theta(T) = \begin{cases} \theta_W(T) & T \leqslant T_{WL} \\ \theta_L & T \geqslant T_{WL} \end{cases}$$

then

$$\theta_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W} \theta(T_I)}{\int_{T_1}^{T_{WL}} (\tau)^{-\beta_W} d\tau + (T_2 - T_{WL})/(T_{WL})^{\beta_W}}$$

and the growth factor is

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left[(T_{WL})^{1-\beta_W} - (T_1)^{1-\beta_W}\right]/(1 - \beta_W) + (T_2 - T_{WL})/(T_{WL})^{\beta_W}}$$

for $T_{WL} < T_W$

Case 2 is when saturation occurs between the time of transition and T_2. This case is depicted in Figure B-3.

7.3.2 Case 2: $T_{WL} > T_W$ and $T_W < T_{WOL} < T_2$

In Case 2, the MTBF reaches the upper limit after transition but before the end of the interval of interest. Then, the cumulative MTBF is

$$\Theta_{LC}(T_1,T_2) = \frac{T_2 - T_1}{\frac{1}{(T_I)^{-\beta_W}\,\theta(T_I)}\int_{T_1}^{T_W}(\tau)^{-\beta_W}\,d\tau + \left[\frac{1}{(T_W)^{\beta_W-\beta_O}\,(T_I)^{-\beta_W}\,\theta(T_I)}\right]\times\left[\int_{T_W}^{T_{WOL}}(\tau)^{-\beta_O}\,d\tau + (T_2 - T_{WOL})/\theta_L\right]}$$

Following evaluation of the integrals and several algebraic substitutions, the growth factor is

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left[(T_W)^{1-\beta_W} - T_1^{\,1-\beta_W}\right]/(1 - \beta_W) + (T_W)^{\beta_O-\beta_W}\left[T_{WOL}^{\,1-\beta_O} - (T_W)^{1-\beta_O}\right]/(1 - \beta_O) + (T_W)^{\beta_O-\beta_W}(T_2 - T_{WOL})/(T_{WOL})^{\beta_O}}$$

The third case is when saturation does not occur until after T_2. This situation is depicted in Figure B-4.

7.3.3 <u>Case 3: $T_2 \leq T_{WOL}$</u>

In Case 3 the MTBF saturates after the period of interest; therefore, limits are not required on either of the integrals evaluated in Cases 1

and 2. Solving the integrals and using several algebraic substitutions yields a growth function

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left[(T_W)^{1-\beta_W} - (T_1)^{1-\beta_W}\right]/(1-\beta_W) + \left[(T_W)^{\beta_O - \beta_W}\right] \times \left[(T_2)^{1-\beta_O} - (T_W)^{1-\beta_O}\right]/(1-\beta_O)}$$

8. SET OF EQUATIONS

The entire set of equations that specify all the growth factors incorporated into the economic analysis model program are presented in this section for completeness.

8.1 Warranty Over the Internal (O,T_W)

$$\theta_W(T) = (T_I)^{-\beta_W}\,\theta(T_I)(T)^{\beta_W}$$

$$\Theta_W(T_1,T_2) = F_W(T_1,T_2)\,\theta(T_I)$$

$$F_W(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left[(T_{WL})^{1-\beta_W} - (T_1)^{1-\beta_W}\right]/(1-\beta_W) + (T_2 - T_{WL})/(T_{WL})^{\beta_W}}$$

for $T_{WL} \leqslant T_2$

$$F_W(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left((T_2)^{1-\beta_W} - (T_1)^{1-\beta_W}\right)/(1-\beta_W)} \quad \text{for } T_2 \leqslant T_{WL}$$

8.2 Full Organic Maintenance Over the Interval (O,NY)

$$\theta_O(T) = (T_I)^{1-\beta_O}\,\theta(T_I)(T)^{\beta_O}$$

$$\Theta_O(T_1,T_2) = F_O(T_1,T_2)\,\theta(T_I)$$

$$F_O(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_O}}{\left[(T_{OL})^{1-\beta_O} - (T_1)^{1-\beta_O}\right]/(1-\beta_O) + (T_2 - T_{OL})/(T_{OL})^{\beta_O}}$$

for $T_{OL} \leqslant T_2$

$$F_O(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_O}}{\left[(T_{OL})^{1-\beta_O} - (T_1)^{1-\beta_O}\right]/(1 - \beta_O)} \quad \text{for } T_2 \leqslant T_{OL}$$

8.3 Organic Maintenance After Transition for the Period (T_W, NY)

$$\theta_{WO}(T) = (T_W)^{\beta_W-\beta_O} (T_I)^{-\beta_W} (T)^{\beta_O} \theta(T_I)$$

$$\Theta_{WO}(T_1,T_2) = F_{WO}(T_1,T_2)\ \theta(T_I)$$

$$F_{WO}(T_1,T_2) = \frac{(T_2 - T_1)(T_W)^{\beta_W-\beta_O} (T_I)^{-\beta_W}}{\left[(T_{WOL})^{1-\beta_O} - (T_1)^{1-\beta_O}\right]/(1 - \beta_O) + (T_2 - T_{WOL})/(T_{WOL})^{\beta_O}}$$

$$\text{for } T_1 \leqslant T_{WOL} \leqslant T_2$$

$$F_{WO}(T_1,T_2) = \frac{(T_2-T_1)(T_W)^{\beta_W-\beta_O} (T_I)^{-\beta_W}}{\left[(T_2)^{1-\beta_O} - (T_2)^{1-\beta_O}\right]/(1 - \beta_O)} \quad \text{for } T_{WOL} > T_2$$

$$F_{WO}(T_1,T_2) = (T_I)^{-\beta_W} (T_{WL})^{\beta_W} \quad \text{for } T_{WL} < T_W$$

8.4 Entire Life-Cycle Interval with a Warranty Period

8.4.1 Case 1: $T_{WL} < T_W$

$$\theta(T) = \begin{Bmatrix} \theta_W(T) & T \leqslant T_L \\ \theta_L & T \geqslant T_L \end{Bmatrix}$$

$$\Theta_{LC}(T_1,T_2) = F_{LC}(T_1,T_2)\ \theta(T_I)$$

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\left[(T_{WL})^{1-\beta_W} - (T_1)^{1-\beta_W}\right]/(1 - \beta_W) + (T_2 - T_{WL})/(T_{WL})^{\beta_W}}$$

$$\text{for } T_{WL} < T_W$$

8.4.2 Class 2: $T_{WL} \geqslant T_W$ and $T_W \leqslant T_{WOL} < T_2$

$$\theta_{LC}(T) = \begin{Bmatrix} \theta_W(T) & T \leqslant T_W \\ \theta_{WO}(T) & T_W \leqslant T \leqslant T_{WOL} \\ \theta_L & T \geqslant T_{WOL} \end{Bmatrix}$$

$$\Theta_{LC}(T_1,T_2) = F_{LC}(T_1,T_2)\ \theta(T_I)$$

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\begin{array}{l}\left[(T_W)^{1-\beta_W} - (T_I)^{1-\beta_W}\right]/(1-\beta_W) + (T_W)^{\beta_O-\beta_W} \\ \times \left\{\left[(T_{WOL})^{1-\beta_O} - (T_W)^{1-\beta_O}\right]/(1-\beta_O) + (T_2 - T_{WOL})/(T_{WOL})^{\beta_O}\right\}\end{array}}$$

8.4.3 Case 3: T_2 T_{WOL}

$$\theta_{LC}(T) = \begin{cases} \theta_W(T) & T \leqslant T_W \\ \theta_{WO}(T) & T \geqslant T_W \end{cases}$$

$$\Theta_{LC}(T_1,T_2) = F_{LC}(T_1,T_2)\ \theta(T_I)$$

$$F_{LC}(T_1,T_2) = \frac{(T_2 - T_1)(T_I)^{-\beta_W}}{\begin{array}{l}\left[(T_W)^{1-\beta_W} - (T_1)^{1-\beta_W}\right]/(1-\beta_W) + (T_W)^{\beta_O-\beta_W} \\ \times \left[(T_2)^{1-\beta_O} - (T_W)^{1-\beta_O}\right]/(1-\beta_O)\end{array}}$$

APPENDIX C

SPARES SUBROUTINE

1. INTRODUCTION

This appendix describes a subroutine that calculates both subassembly and module spares. Specific features of the subroutine include pipeline definitions employed by MOD-METRIC, three types of sparing (no subassembly repair at base, subassembly repair at base, and module sparing), base and depot spare calculations, and a simplified back-order calculation at the depot. The back-order provision considers the fact that because of demand, spares may not be available at the depot, thereby causing a back order and resulting in a depot-delay increment time. This delay must be included in the associated pipeline times.

The subroutine can accommodate a number of bases for a single depot. Only one depot can be considered, and the bases are assumed to have an equal number of installations operating an equal number of hours.

2. BASIC APPROACH

The basic approach was to design a subroutine that could accommodate the three different pipeline calculations and incorporate a simplified version of the MOD-METRIC back-order calculation.

A general flow diagram of the subroutine is shown in Figure C-1. After the subroutine is initialized, it chooses a depot spare level, which is usually set equal to one. It then initiates a loop on depot spares. The first step is to calculate the appropriate pipeline time. As shown in Figure C-1, there are three subroutine pipeline-time-calculation paths.

During the pipeline calculations, the depot-delay increment time is calculated for the existing depot spare level. At this point, a decision is made as to which type of sparing algorithm will be employed. There are two sparing algorithms -- one employs the Poisson process and one has been designated fractional sparing. The requirement for fractional sparing is a consequence of the low levels of demands observed in the ground equipment world. Since these low levels of demands reduce the population size of demands for the Poisson process, the fractional sparing has been incorporated. After choosing the proper sparing algorithm, the spares for the

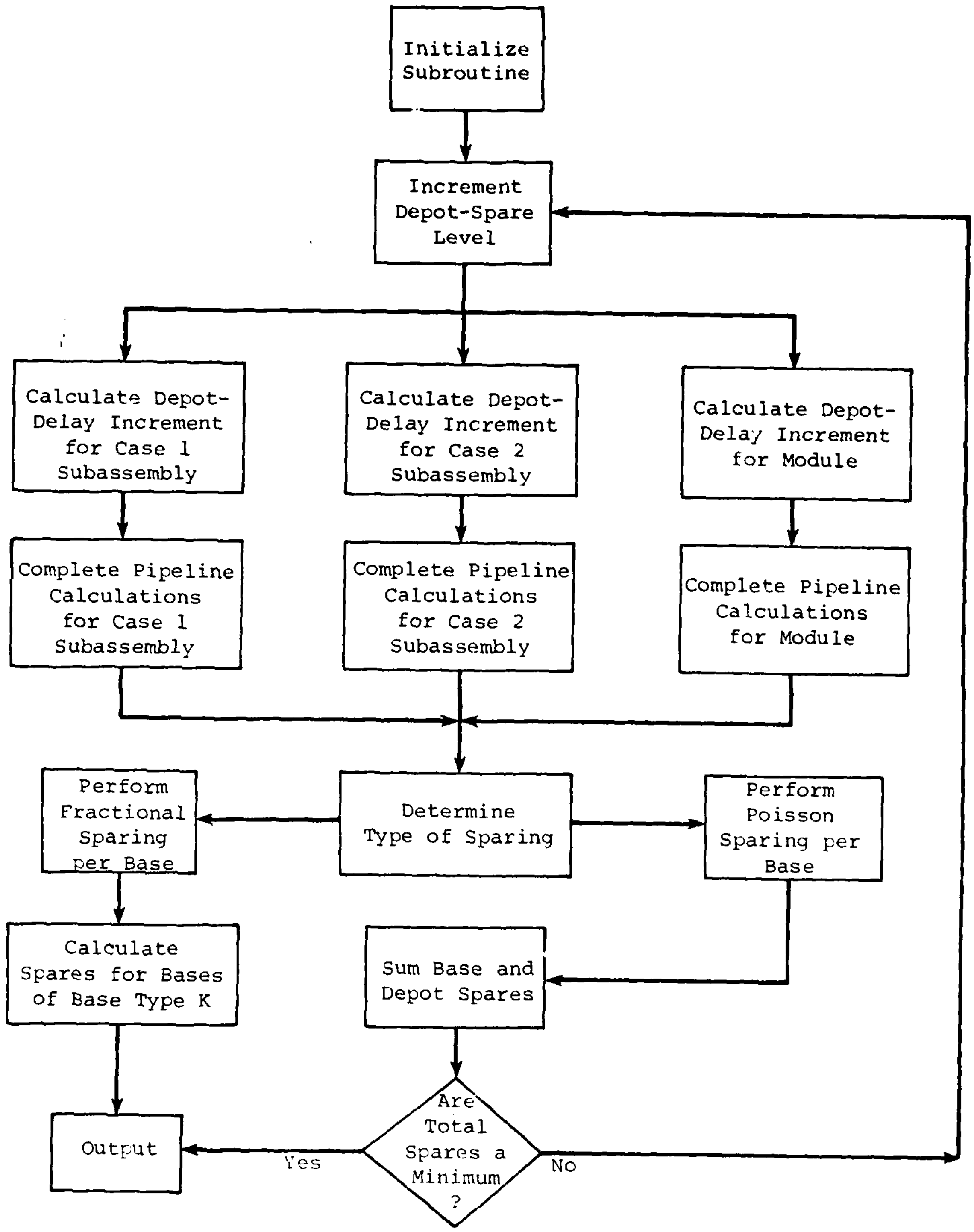

Figure C-1. GENERAL FLOW DIAGRAM OF SPARES SUBROUTINE

base type are calculated. When fractional sparing is chosen, the spares for that base type are calculated, and execution is returned to the main program. If the Poisson sparing algorithm is chosen, the spares for the base type are calculated and then summed with the depot spares to yield the total spares. A determination is made as to the minimum amount of total spares. This loop on the depot-spares level is continued until a minimum value is identified. At that point the subroutine has completed its task and outputs to the main routine.

3. SPECIFIC TASKS

The subroutine includes four major tasks:

- Spares computation
- Pipeline computation
- Depot-delay increment time computation
- Minimum total spares selection algorithm

The following subsections describe each of these tasks.

3.1 Spares Computation

As discussed previously, there are two sparing algorithms -- fractional sparing and the Poisson process. The choice between the two algorithms is made by comparing the pipeline demand product with a preset value of 1.5. If this product is less than or equal to 1.5, then the fractional sparing algorithm computes the spares for that base type and exits the subroutine. If the time demand product is greater than 1.5, the Poisson sparing algorithm is utilized.

3.1.1 Fractional Sparing

The fractional sparing algorithm simply considers the time demand product as the fractional demand for base type. To complete all the spares for base type k, a spare for the depot is added to the fractional demands. This value is outputted to the main program, which sums the contributions for each base type and then rounds up to the next whole number of spares.

3.1.2 Poisson Sparing

For the Poisson sparing algorithm, the sparing approach employed is based on the assumption that demands follow a Poisson process. If the maintenance demand rate is D per day for items from a spares pool and if the average pipeline time to replenish the spares pool is P days, then the number of spares required to meet a spares-sufficiency level (PSUFF) for a steady-state condition is the smallest integer value of S that satisfies the formula

$$\sum_{n=0}^{S} \frac{e^{-(P \times D)}(P \times D)^n}{n!} \geq P_{SUFF}$$

This computation is performed by a function designated as ISPARE in the subroutine.

3.2 Pipeline Computations

The pipeline times must be considered on a per-case basis. For Case 1, there is no subassembly repair at the base. The Case 1 pipeline structure is illustrated in Figure C-2. The average Case 1 pipeline time, T_G, is

$$T_G = P_{RTOK} \times T_B + [1 - P_{RTOK}] \times [T_{OSS} + T_{IG} + T_B]$$

where

P_{RTOK} = probability of "Retest OK" at the base

T_{OSS} = order and ship time for subassemblies (starts when item is reordered until time that item arrives and is put in base stock)

T_{IG} = depot-delay time increment for a subassembly

T_B = base-cycle processing time

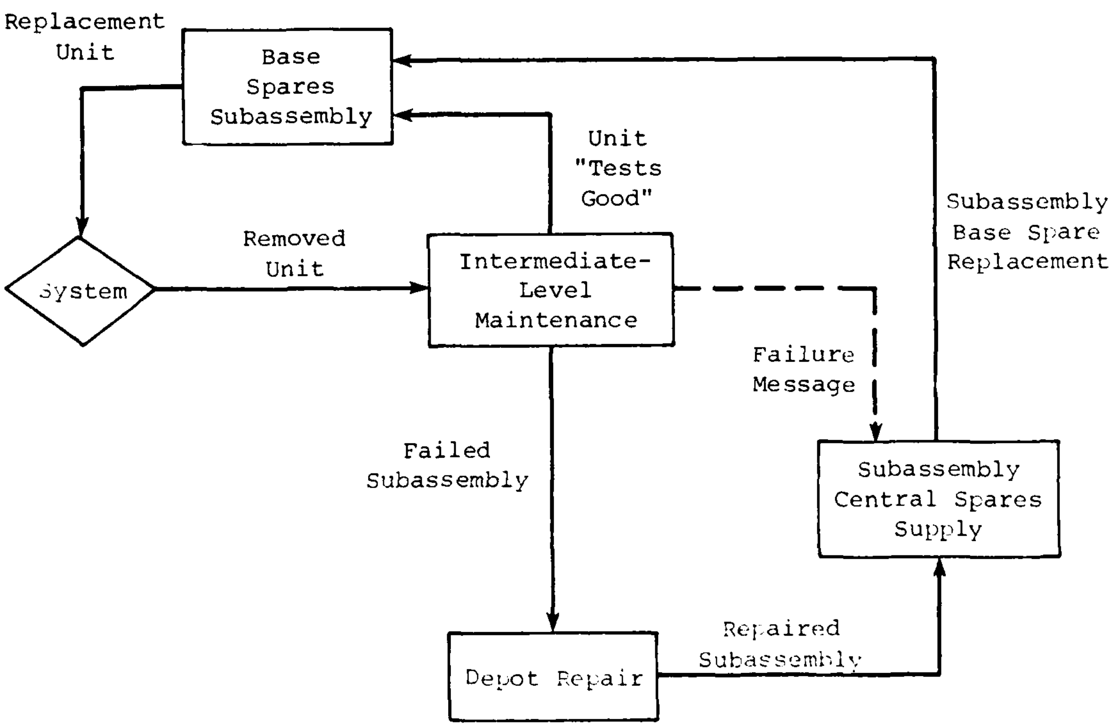

Figure C-2. LOGISTIC PIPELINE FLOW FOR CASE 1 SUBASSEMBLY SPARING

Case 2 is when subassemblies are repairable at the base. The pipeline structure is illustrated in Figure C-3 for Case 2. The average pipeline time, T_{NG}, is

$$T_{NG} = [P_{RTOK} \times T_B] + [P_{NRTS} (T_{OSS} + T_C + T_{IG})] + (1.0 - P_{RTOK} - P_{RTS})$$
$$\times [P_{SRU} \times T_B + P_{NSRU} \times (T_{OSM} + T_{IS} + T_B)]$$

where

P_{NRTS} = probability of not repairable at the base

P_{SRU} = probability of having a module to repair the subassembly

$P_{NSRU} = 1 - P_{SRU}$

T_{OSS} = order and ship time for a subassembly (same as for Case 1)

T_{OSM} = order and ship time for a module

T_C = depot-repair cycle time that starts when the subassembly enters base checkout and includes base-repair cycle time, transportation to depot, and repair and placement into stock

T_{IS} = the weighted average depot-delay increment time of all modules for the subassemblies of interest (it should be noted that *this is an input parameter to the subroutine)*

This first term of T_{NG} considers those items which "retest OK" at the base. The second term considers those items which are not repairable at the base and are sent to the depot. The third term of T_{NG} considers those items which are repairable at the base (where $P_{SRU} \times T_B$ represents repairing the subassembly with the necessary module at the base), and P_{NSRU} $(T_{OSM} + T_{IS} + T_B)$ considers that the required module may not be available at the base and therefore must be obtained from depot supply. This latter term also considers that the required module may not be available at the depot. This time, T_{IS}, is a weighted depot-delay increment time of all the modules for subassembly of interest and is inputted to the subroutine. T_{IG} is calculated in a similar way as in Case 1.

The T_{IS} for the i^{th} subassembly, denoted by T_{IS_i}, can be calculated as follows

$$T_{IS_i} = \sum_{j=1}^{n} P_{ij} \, T_{ij}$$

where

T_{ij} = the depot-delay increment time for the j^{th} modules in the i^{th} subassembly

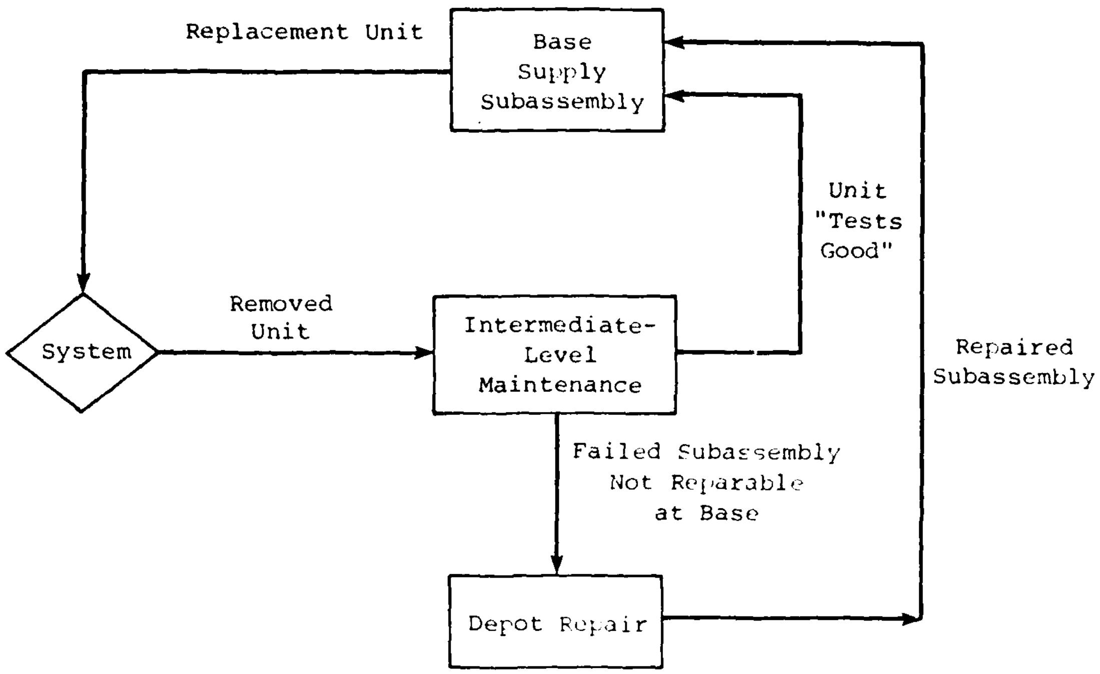

Figure C-3. SUBASSEMBLY PIPELINE FLOW FOR CASE 2

$p_{ij} = \lambda_{ij} / \sum_{j=1}^{n} \lambda_{ij},$

probability that the j^{th} module in the i^{th} subassembly requires repair given that one of the modules needs repair

λ_{ij} = demand rate for the j^{th} module in the i^{th} subassembly

Case 3 is the module sparing case. The modules are repaired and stocked at the base. The pipeline structure is illustrated in Figure C-4 for Case 3.

The average pipeline time for a module is

$$T_S = (T_{OSM} + T_{IS} + T_B) \times P_{NRTS} + (1 - P_{RTOK} - P_{NRTS}) \times T_B + P_{RTOK} \cdot T_B$$

$$= (T_{OSM} + T_{IS}) P_{NRTS} + T_B$$

where

T_{OSM} = order and ship time for a module from the depot to the base

T_{IS} = the depot-delay increment time for the module due to nonavailability of the module at depot supply

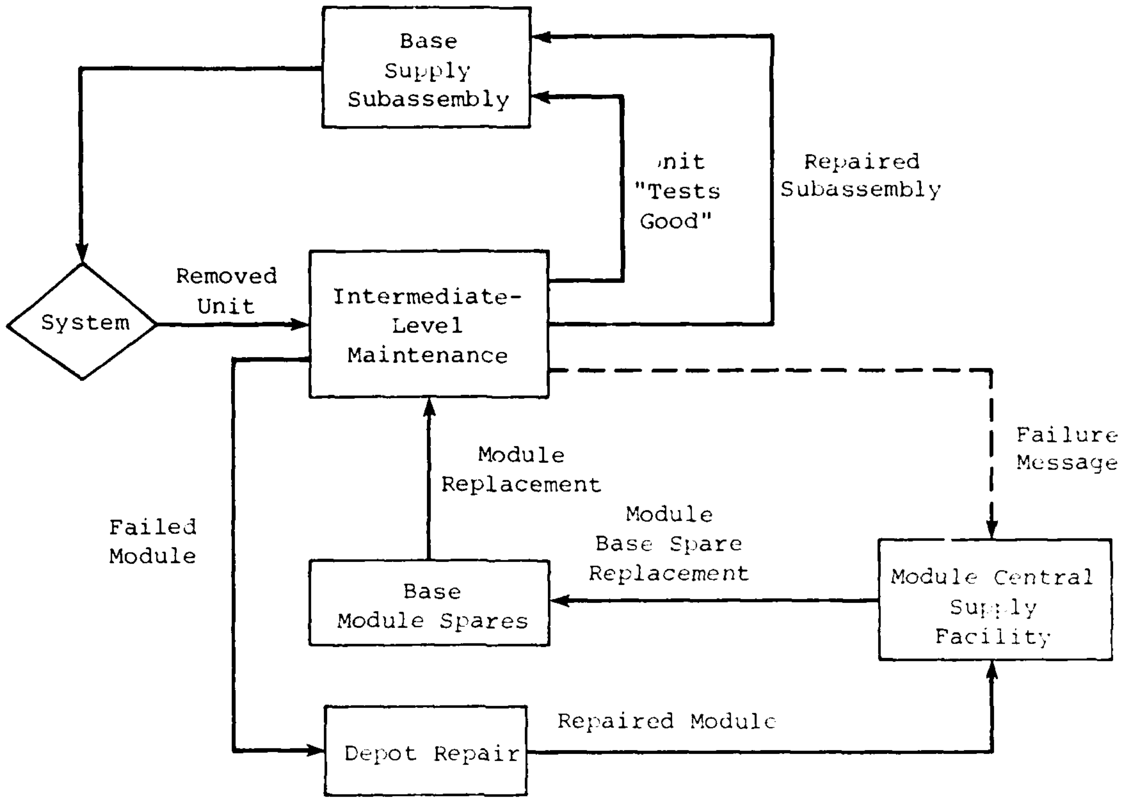

Figure C-4. MODULE PIPELINE FLOW

3.3 Depot-Delay Increment Time Calculation

The depot-delay increment time is calculated from the expected number of back orders at the depot. The expected number of back orders at a random point in time is equal to the expected number of units for which a delay is being incurred, and this is equal to the expected number of delayed days per day at the depot. Dividing this quantity by the expected number of demands per day yields the expected number of delay days per demand, which is equivalent to the depot-delay increment time.

This depot-delay increment time (T_I) is defined as

$$T_I = \frac{EBO}{\lambda_D}$$

where

EBO = the expected number of back orders at the depot

$\lambda_D = N_T H \lambda_d$, the depot demand rate

N_T = total number of installations

H = operating hours per day

λ_d = $\lambda(1 - P_{RTOK})$, demand rate per hour at depot

λ = demand rate per hour at base

P_{RTOK} = probability of "retest OK" at base

The expected number of back orders at the depot is

$$EBO = \sum_{n=S+1}^{\infty} \frac{(n - S)(e)^{-\lambda_D T_D} (\lambda_D T_D)^n}{n!}$$

where

S = depot spares

T_D = depot-cycle repair time (starts after failure determination and includes shipping time, repair at depot, and replacement in depot stock)

For convenience, let

$$A_n = \frac{(e)^{-\lambda_D T_D} (\lambda_D T_D)^n}{n!}$$

Then

$$EBO = \sum_{n=S+1}^{\infty} (n - S) A_n$$

$$= \sum_{n=S+1}^{\infty} nA_n - S \sum_{n=S+1}^{\infty} A_n$$

$$= \sum_{n=0}^{\infty} nA_n - \sum_{n=0}^{S} nA_n - S \sum_{n=0}^{\infty} A_n + S \sum_{n=0}^{S} A_n$$

However,

$$\sum_{n=0}^{\infty} nA_n$$

is the expected value of n, which is $\lambda_D T_D$, and the $\sum_{0}^{\infty} A_n$ is equal to one.

Therefore,

$$EBO = \chi_D T_D - \sum_{n=0}^{S} n\, A_n - S + S \sum_{n=0}^{S} A_n$$

$$EBO = \chi_D T_D - S + \sum_{n=0}^{S} \frac{\left[(S - n)\ (e)^{-\chi_D T_D}\ (\chi_D T_D)^n\right]}{n!}$$

The depot-delay increment time is

$$T_I = T_D - S/\chi_D + \sum_{n=0}^{S} \frac{(S - n)(e)^{-\chi_D T_D}\ (\chi_D T_D)^n}{n!\,\chi_D}$$

This expected back order is computed in a function designated as EBO in the subroutine.

3.4 Minimum-Total-Spares Selection Algorithm

As shown in the equation for T_I, the delay increment time is dependent on the number of depot spares. To determine the optimum number of spares, a cycle is established in which the depot spares level is incremented. For each depot spare level, the delay increment time is computed and then incorporated into the pipeline time, which is then employed to determine the base spares level for a unit. It is desirable to have the minimum amount of total spares for that unit (i.e., base and depot spares combined). This determination is made by a selection algorithm, which employs a four-point running average of the total spares. If the most recent computation of total spares is greater than the current average, the cycle is stopped. Once the cycle is completed, the depot spare level yielding the lowest total spare value is chosen. This algorithm is employed when Poisson sparing is chosen.

4. COMPUTER IMPLEMENTATION

A listing of the subroutine starts at line number 16250 of the program listing provided in Appendix A. The arguments for the subroutine are as follows:

J — Denotes Pipeline Type, Outputted

- 1 - Subassembly not repaired at base
- 2 - Subassembly repaired at base
- 3 - Modules

INPT — Total Number of Spares, Outputted

IDS — Number of Depot Spares, Outputted

BPRTOK Base "Retest OK" Probability, Inputted

DTROK Processing Time for BPROK Item in Days, Inputted

DRTL Depot Repair Cycle Time (Days), Inputted

TOSS Order and Ship Time (Days) for Subassemblies, Inputted

TOSM Order and Ship Time (Days) for Modules, Inputted

PNRTSS Probability of Not Repairable at the Base for a Subassembly, Inputted

PNRTSM Probability of Not Repairable at the Base for a Module, Inputted

PSUFF Probability of Spares Sufficiency, Inputted

DSRU Base-Cycle Repair Time (Days), Inputted

H Average Number of Operating Hours per Installation per Day, Inputted

NB Number of Installations, Inputted

PMTBD MTBD for Unit in Hours, Inputted

TINC Depot-Delay Increment Time in Days, Inputted for Case 2, Outputted for Case 3

SPARES Number of Fractional Spares, Outputted

Most of the arguments are self-explanatory; thus their usage should present no problems. However, there are two arguments, J and TINC, that require a further explanation. The argument J is a flag for the subroutine that tells the subroutine which pipeline calculation to choose. By the appropriate selection of J = 1, 2, or 3, the subroutine will calculate the spares for the desired type of unit.

The argument TINC has a double role. When computing the Poisson spares for Case 3 modules, the subroutine will set TINC equal to the determined depot-delay increment time. Thus the main program can store the value of TINC for every module in a given subassembly. Values can then be weighted in any desired manner in the main program. When computing the spares for Case 2, TINC is the weighted average depot-delay increment time for the subassembly. This weighted average can be shown as follows: In the Case 2 pipeline when a subassembly is determined to be a failure and is repaired at the base, a possibility exists that the desired module to repair the subassembly is not at the base or not at the depot supply. To account for this set of events, a weighted average of the module depot-delay increment time was required. Instead of computing the quantity in the subroutine, it was decided to input this parameter into the subroutine.

5. EXAMPLES OF THE USE OF THE SUBROUTINE

This section addresses a few examples of exercising the spares subroutine. Consider the following set of parameters for a subassembly:

- Base cycle time - 15 days
- Order and ship time - 45 days
- "Retest OK" probability at base - 0.1
- Depot-repair cycle time - 90 days
- Probability of not-repairable-at-base for the subassembly and for the module - 1.0 percent
- Probability of spares sufficiency - 0.90
- Number of installations - 500
- Average operating hours per day per installation - 24
- Mean time between demands - 10,000 hours

An assumption has been made that the processing time for a "retest OK" at base is equal to the base-cycle time. With a probability of not-repairable-at-base equal to one, the unit is a Case 1 option. The input call to the subroutine would be:

```
CALL SPARE (1, ISPT, IDS, .1, 15., 90., 45., 45., 1.0, 1.0, 0.90,
           15., 24., 500., 10000., TINC, SPARES)
```

The results of five different MTBDs are shown in Table C-1.

Table C-1. EXAMPLE RUN FOR CASE 1

MTBD (Hours)	Depot Spares	Total Spares	TINC (Days)
5,000	144	311	8.52
7,500	97	210	8.15
10,000	70	159	10.59
12,500	60	129	7.09
15,000	48	108	9.46

Note for this case that TINC does not monotonically increase with increasing MTBD. The selection algorithm is minimizing the total number of spares of which TINC is only one variable. In some cases it is better to have a larger TINC, thus requiring less depot spares resulting in fewer total spares.

As a second example, consider a module with the same inputs as for the subassembly discussed in the first example. Vary the MTBD from 25,000 to 75,000 hours. The call to the subroutine would be:

```
CALL SPARE (3, ISPT, IDS, .1, 15., 90., 45., 45., 1.0, 1.0, 0.9,
           15., 24., 500., 50000., TINC, SPARES)
```

The results of five different MTBDs are shown in Table C-2.

Table C-2. EXAMPLE RUN FOR CASE 3

MTBD (Hours)	Depot Spares	Total Spares	TINC (Days)
25,000	31	62	6.98
37,500	21	43	7.48
50,000	16	33	7.85
62,500	13	27	8.15
75,000	11	23	8.39

Since this last example was for a module, assume that five modules constitute a Case 2 subassembly. Then the TINCs from each module can be weighted as follows:

$$Tw_i = \sum_{j=1}^{n} P_{ij}\, T_{ij}$$

where

T_{ij} = depot-delay increment for the j^{th} module in subassembly

$P_{ij} = \lambda_{ij} / \sum_j \lambda_{ij}$

probability that the j^{th} module in the i^{th} subassembly fails given that the i^{th} subassembly has a failure

λ_{ij} = demand rate for the j^{th} module in the i^{th} subassembly

The weighted depot-delay increment time for the Case 3 example has been calculated at 7.57 days.

Consider a Case 2 subassembly with the same parameters as the example for Case 1, except tnat the probability of Not Repairable This Station for the subassembly is equal to 0.08. The call to the subroutine would be:

```
CALL SPARE (2, ISPT, IDS, 0.1, 15., 90., 45., 45., 0.08, 1.0, 0.9,
           15., 24., 500., 10000., 7.57, SPARES)
```

The results of five different MTBDs are shown in Table C-3.

Table C-3. EXAMPLE RUN FOR CASE 2

MTBD (Hours)	Depot Spares	Total Spares	TINC (Days)
5,000	31	62	7.57
7,500	21	43	7.57
10,000	16	33	7.57
12,500	13	27	7.57
15,000	11	23	7.57

APPENDIX D

PROVISIONS FOR WARRANTY AND MTBF GUARANTEE PLANS

The provisions contained in the following pages represent a collection of warranty and MTBF guarantee terms and conditions that have been drawn from actual applications. The user should be advised that these terms and conditions do not apply to any specific item of equipment and would require modification to meet the circumstances unique to a specific application. Explanatory comments regarding modifications are also included.

WARRANTY WITH MTBF GUARANTEE

PART I - INTRODUCTION (1)*

1.1 This introduction provides an overview of the specific contractual requirements contained in Parts II through VII of these provisions. The purpose of this warranty-guarantee is to induce the contractor to design reliability and maintainability (R&M) into the equipment. The warranty-guarantee extends the contractor's responsibility for a period of time beyond delivery of the equipment and provides an incentive to the contractor to further improve the equipment's reliability and maintainability at no additional cost to the Government above the fixed price.

1.2 The following two separate options (2) are provided:

(a) A reliability warranty. Under this warranty option the contractor is required to correct or replace, at his option and at no additional cost to the Government, any equipment that fails during the warranty period. Maximum latitude shall be given to the contractor to make no cost changes to improve R&M.

(b) A reliability warranty and MTBF guarantee. This option is the same as that in Paragraph 1.2(a) except that in addition to performing no-cost-to-the-Government repair, the contractor also guarantees that a stated MTBF will be achieved in field operation.

1.3 The warranty is for a five (5) (3) year period, commencing with Government acceptance of the first production unit.

1.4 The projected usage rate is provided in Table D-1. (4)

1.5 The Government is responsible for managing the warranted unit spares inventory positioned at any operational location. The Government will purchase spare units on the basis of established provisioning procedures. These spare units will be placed in the contractor's bonded storage area. (5) The contractor will be responsible for managing this spares inventory. When a demand for a unit exists in the field, the contractor will be notified by a Material Release Order, and he shall promptly provide a replacement unit.

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*Circled numbers refer to explanatory comments provided at the end of this appendix.

1.6 The contractor is required to provide consignment spares at specified intervals if his repair turnaround time is greater than that contractually required.

1.7 For the MTBF guarantee option, the contractor is required to provide consignment spares at specified intervals if the actual measured MTBF is less than the contractually required MTBF.

1.8 At the end of the warranty period the contractor is required, at no additional cost to the Government, to provide necessary modification kits and data to permit the Government to modify all units to the latest approved configuration.

PART II - STATEMENT OF CONTRACTOR WARRANTY

2.1 Notwithstanding the conclusiveness of final inspection and acceptance of supplies and services furnished under this contract, the contractor warrants that the units listed in Section E (Schedule) 6 shall be free from defects in design, material, and workmanship and shall operate in their intended environment in accordance with applicable Technical Orders and specifications for a five (5) year warranty period. The warranty period shall begin upon Government acceptance of the first production unit and shall terminate five (5) 3 years from that date.

2.2 Any unit that fails to meet this warranty shall be returned to the contractor's designated repair facility at Government expense. The unit shall be either corrected and modified or replaced at the contractor's sole option and expense so as to operate in accordance with specification 7 ________. The unit as corrected or replaced and accepted by the Government in accordance with approved Repair Verification Test Procedure 7 ________ shall be placed in bonded storage.

2.3 A failure is defined as any warranted unit returned to the contractor because it does not perform in accordance with specification 7 ________.

2.4 The contractor shall not be obligated to repair or replace, at no cost to the Government, any item warranted hereunder that is lost or damaged by reason of fire, explosion, submersion, flood, enemy combat action, or tampering by Government personnel, unless the occurrence of fire or explosion was a result of nonconformance of the warranted item. In addition, the contractor shall not be obligated under these warranty provisions for:

(a) Repair of external physical damage caused by accidental or willful mistreatment, or

(b) Repair of internal physical damage that, in the determination of the Government, has been caused by accompanying external physical damage due to mistreatment or tampering by noncontractor personnel.

There is a presumption that a warranted item or module, which is returned to the contractor's repair facility during the warranty period, is covered under this warranty and that only the exclusions listed above shall void the contractor's responsibility to test, repair, or replace at no increase in contract price under this warranty. No distinction is to be drawn between type of failure, such as relevant versus nonrelevant.

2.5 The rights and obligations of the parties under this warranty are in addition to and independent of the rights and obligations of the parties under the other provisions of this contract including the Correction of Deficiencies Clause cited therein. The contractor shall not be liable for special consequential or incidental damages.

PART III - CONTRACTOR OBLIGATIONS

3.1 The contractor agrees to retain responsibility for configuration management and systems performance for all equipment under warranty. All contractor-developed and -initiated warranty ECPs for improved reliability or maintainability of the units that are approved by the Government shall be incorporated at no change in contract price, including incorporation of such changes to the affected units and updating of support equipment and technical data directly resulting therefrom. Proposed changes shall be submitted pursuant to the appropriate provisions of this contract and shall be clearly designated as a warranty ECP. The contractor shall maintain configuration control by serial number. All changes to configuration, design, part, Technical Order (T.O.), support equipment, etc., that affect form, fit, or function of the warranted items shall be submitted to the Contracting Officer for approval. Changes not affecting form, fit, or function shall be documented, accomplished, and reported to the Government. As each item is repaired by the contractor, it shall be modified to the latest approved configuration. It is intended that at the end of the warranty period all items and associated T.O.s, support equipment, etc., shall be in the latest approved configuration. Those items in the inventory at the end of the warranty period which are not in the latest approved configuration shall be modified by the Government by using kits and T.O.s supplied by the contractor under these warranty provisions. The kits and T.O.s referred to above shall be supplied by the contractor as a part of these warranty provisions and at no change in the fixed price for such warranty.

3.2 In meeting the warranty provisions specified in Part II above, the contractor shall comply with the following:

(a) The contractor shall maintain the records required by Part VII hereof and by serial number for each unit under warranty. These records shall be made available to the Government as required and shall be available for review during the warranty period and for three (3) years thereafter.

(b) The contractor shall provide and install seals for all warranted units to preclude tampering. 8 The design of the seals shall be such that inadvertent seal breaking is minimized. The contractor shall submit the proposed seal design to the PCO for approval. A broken seal in and of itself shall not be evidence of unauthorized maintenance. An exclusion exists only when the cognizant ACO determines that there was obvious internal tampering which induced the failure.

(c) The contractor shall, in addition to the identification plate: 8

(1) Place on each unit a display that will provide, as a minimum, information that the unit is under warranty, the warranty expiration date, failure data requirements, and shipping instructions.

(2) Place on each unit a decal for field personnel to record the date the unit is installed and the date of removal. The proposed format(s), application(s), construction, and proposed location(s) of the plate and decal shall be submitted to the PCO for approval.

(d) The contractor shall also place warranty information in any Technical Orders applicable to the warranted unit. The T.O.s shall also provide instructions for any maintenance actions that may be performed by organizational or intermediate personnel without voiding this warranty.

(e) Preservation, packaging, packing, and marking at the contractor's facility shall be in acordance with Section G of the contract and shall be at the contractor's expense. The contractor shall mark the shipping container(s) used for transport of warranted units with the external citation "WARRANTED ITEM" in bold letters.

(f) The contractor shall maintain throughout the warranty period at least one (1) fully operational warranty repair facility. The location of such facility shall be subject to the approval of the Procuring Contracting Officer. The contractor shall also maintain at each repair facility a secure storage area 5 (i.e., bonded storeroom) for spare and repaired units. The contractor shall provide all necessary facilities, tooling, and equipment of any type necessary for the successful performance of this warranty (except for the ARS AUTODIN terminal needed to accomplish asset reporting). The contractor shall provide necessary personnel to operate the AUTODIN 5 terminal as well as terminal supplies. Property control of any returned units will be in accordance with ASPR Appendix B "Manual for Control of Government Owned Property in Possession of Contractors."

(g) When a requirement is generated in the field, the Item Manager shall promptly notify the contractor via the Autodin Advanced Records Systems, giving shipping instructions for units to satisfy the requirement. This requirement will be in the form of a

Material Release Order (MRO). Upon receipt of such notification, the contractor shall ship a replacement unit from the bonded storage area to the facility designated by the Government. To the extent possible, a first-in/first-out basis shall be used in selecting units for shipment from the storage area. Such shipment will be made within 24 hours after receipt of the Material Release Order. Only Saturdays, Sundays, and contractor-/union-recognized holidays shall be considered nonworking days. If receipt of the MRO occurs on a contractor's nonworking day, the 24-hour period shall begin at the start of the contractor's first workday following notification. 9 The contractor shall use a Government Bill of Lading accompained by DD Form 1348 or DD Form 1149 for transfer of Government property accountability.

3.3 If the contractor considers that the unit returned is covered by one of the exclusions in Part II, Paragraph 2.4, the contractor shall submit the circumstances to the Adminstrative Contracting Officer together with a not-to-exceed price and schedule for repair. If the ACO determines that correction or replacement is not within the terms of this warranty, repair of the equipment shall be the subject of a separate procurement action. Equipment so repaired shall continue to be warranted for the remaining warranty period at no change in contract price. If the ACO determines that the equipment is not covered within the terms of the warranty and is not correctable, the equipment shall be disposed of as directed by the ACO.

3.4 The contractor shall be responsible for obtaining spare parts for use in repair and/or modification. These parts remain the property of the contractor until incorporated into a unit at which time title for these parts passes to the Government. All spare parts shall be in accordance with approved drawings and specifications. Any failed (a) material removed and replaced or (b) unit replaced, pursuant to this warranty shall become the property of the contractor.

3.5 The Government reserves the right to perform inspection at the contractor's repair facility. All items returned for repair and/or modification under the provisions hereof shall be subject to special Repair Verification Test Procedures________. 7

3.6 Units returned and covered under this warranty for which the failure cannot be verified and which pass the Repair Verification Test Procedure shall be covered by this warranty at no additional cost to the Government. 10

3.7 The contractor shall, within the number of calendar days specified in Section E (Schedule), correct or dispose of and replace units and install approved modifications as necessary, and after passing Repair Verification Test Procedures, physically store the returned unit in a bonded storage area. This turnaround time requirement shall apply to all units returned except those to which one or more of the exclusions listed in Part II, Paragraph 2.4 apply.

3.8 Calculation of average turnaround time shall be made every six (6) months of the warranty period for each type of unit. The first such period shall start at the time of final acceptance by the Government of the first unit. If the average turnaround time in a six (6) month period is greater than the turnaround time specified in Section E, as computed from warranty data records, the contractor will be required to provide the Government consignment spares consistent with the MTBF Guarantee values specified in Section E and in accordance with the following: 11

$$n = AOT \left(\frac{\overline{N}}{G}\right) (T_m - T_r) - L_p$$

where

n = number of turnaround-time consignment spares to be furnished (n rounded to next higher integer)

AOT = average operating time per day per unit calculated as follows:

$$AOT = \frac{\Sigma H_i}{\Sigma T_i}$$

where

T_i = number of days each returned unit was installed

H_i = number of operating hours for each returned unit during T days

$\overline{N}$ = average number of installed units defined as follows:

$$\overline{N} = \frac{1}{6} \sum_{j=1}^{6} \frac{N_j + N_{j-1}}{2}$$

N_j = number of units that are installed on the last day of each month (j) of the six (6) month measurement period

N_j-1 = number of units installed on the last day of the previous month of the measurement period

G = unit MTBF guarantee value for the corresponding measurement period, as specified in Section E, defined as the projected total operating hours (PTOH), as specified in Section E, for such installed units in the Government inventory during a specified period divided by the total number of projected failures during the same period. (Note: If guarantee value is not used, contractor and Government should use agreed-upon values)

T_m = measured average turnaround time in days is the average number of days each type of unit is in the contractor's possession, from the day it arrives at the contractor's facility until it is physically placed in bonded storage as a serviceable unit, packaged, and ready for issue

T_r = turnaround time commitment as specified in Section E

L_p = spares currently consigned to the Government as a result of repair-turnaround-time commitment provisions

(a) A positive value of n represents the liability of the contractor for consignment spares under the repair-turnaround-time commitment provisions of this warranty.

(1) The contractor shall provide such consignment spares to the Government within forty-five (45) days. (12) However, the actual quantity of such consignment spares shall be no greater than the number of occasions when an item is required by the Government and was not shipped within the required period because of insufficient assets in the contractor's bonded storage area.

(2) For each consignment unit not supplied within the appropriate period, the contractor will pay the Government at the rate of 1.67 percent (12) of the unit price for each day late. However, this payment shall not be more than 100 percent of the unit price.

(b) If n in the above equation is negative, the Government shall return any consignment spares in its inventory within sixty (60) (12) days up to an amount equal to the absolute value of n.

(c) In no case shall the number returned be greater than the quantity originally consigned by the contractor. The units returned shall be either consignment units provided by the contractor or equivalent units provided under this or another contract.

3.9 The contractor shall have a continuing responsibility to perform under this warranty for any item shipped to the contractor's repair facility with a shipping date on or before the last day of the warranty period.

PART IV - GOVERNMENT OBLIGATIONS

4.1 The Government shall:

(a) To the extent practicable, verify all failures in accordance with applicable Technical Orders prior to return of the unit to the contractor.

(b) Provide shipping instructions. When a failure occurs in the field, the Item Manager shall promptly notify the contractor via the Autodin Advanced Records System, (13) giving shipping instructions for items to satisfy the demand. Shipments of failed units to the contractor's repair facility, and shipments of units from the contractor's repair facility shall be at Government expense on a Government Bill of Lading.

(c) Provide field- and intermediate-level maintenance on those actions specified in applicable T.O.s, using the specified Technical Order Procedures.

(d) To the extent practicable, furnish the installation and removal dates of all failed units. In addition, the Government shall furnish failure data and test readings, on AFTO Form 350, for all failed units when the units are returned to the contractor, as specified in T.O. series 00-20.

(e) If an ETI is installed on the unit, furnish ETI readings at the time of installation and removal. If an ETI is not installed, furnish the number of operating hours during the installation period. 4

(f) Agree that all no-cost RIW Class I ECPs submitted to improve reliability and maintainability shall automatically stand as approved by the Government forty-five (45) 12 days after receipt by the PCO, unless the Contractor is notified of disapproval in writing prior to that date. Disapproval of any no-cost RIW Class I ECP shall in no way relieve the contractor of his obligations pursuant to this contract. A unilateral no-cost change order shall be issued to authorize the change.

(g) Determine the quantity of consignment spares to be provided in accordance with Paragraphs 3.8 and 5.2.

(h) Witness contractor-conducted testing and review the test documentation at the Government's option.

(i) During the warranty period, return the excess number of units as determined in Paragraphs 3.8 and 5.2 as soon as possible but no later than sixty (60) 12 days after receipt of the warranty data report if the calculations indicate that such return is required.

(j) At the end of the warranty period, return all consignment units provided in accordance with Paragraph 3.8 and the excess number of consignment units determined in accordance with Paragraph 5.2. All other consignment units shall become Government property.

(k) Provide, on a monthly basis, the quantity of warranty units installed on the last day of each month.

(l) Ship all units in approved containers, and if reusable containers are the approved means, maintain an adequate supply for shipment of units to and from their destination.

(m) Provide an ARS Autodin terminal, as required, for accomplishing asset reporting and training for the contractor-provided terminal operator(s).

PART V - MTBF GUARANTEE

If this option is exercised, the contractor shall guarantee that the warranted units will achieve an MTBF equal to or greater than that indicated in Section E.

5.1 As used in this guarantee, unit MTBF is defined as the total operating hours of all units in the Government inventory that were accumulated during a measurement period divided by the total number of verified failures of all such units during the same measurement period. Failures are as defined in Paragraph 2.3.

5.2 For each type of unit the contractor shall calculate the MTBF achieved over the previous six (6) month period. The first such measurement shall be made twelve (12) months after the final Government acceptance of the first production unit. The following explains how such measurements shall be made:

$$M = \frac{TOH}{F}$$

where

M = achieved MTBF of unit

F = number of failures of the unit (as defined in Paragraph 2.3) occurring during the measurement period

TOH = total operating hours during six (6) month measurement period, calculated as follows:

$$TOH = \overline{N} \times D \times AOT$$

where

$\overline{N}$ = average number of installed units, as defined in Paragraph 3.8

D = number of days in the measurement period

AOT = average unit operating time per day per unit, as defined in Paragraph 3.8 4

5.3 In calculating the above:

(a) Only units (and operating hours therefrom) that are returned during the warranty period shall be counted.

(b) Operating time while at the contractor's facility shall be excluded. Returned units for which the elapsed time is not available shall be included in the calculation of the average operating hours per day by using the average operating hours of all returned units with available elapsed times.

(c) Returned units that have missing installation or removal dates shall be considered to have been installed the calculated average number of days of all returned units with available installation and removal dates.

(d) Returned units with missing operational hours on date of removal shall be considered to have been operated the calculated average number of operating hours of other returned units with available operational hours.

(e) The Contracting Officer will review the contractor's calculation and supporting data of AOT.

5.4 In the event that an achieved MTBF at the end of the second measurement period (13 to 18 months) and succeeding measurement periods is less than that of a corresponding MTBF guarantee value (stated in Section E), the contractor shall furnish the following to the Government at no increase in contract price:

(a) Engineering analysis (including failure modes and effects analysis) to determine the cause for nonconforming MTBF in accordance with Part VII, Paragraph 7.1.

(b) On the basis of the above analysis, No-Cost Engineering Change Proposal(s) pursuant to MIL-STD-480, and subsequent to Government approval of said ECP(s), modification (at no cost to the Government) of all items, spares, spare parts, support equipment, software and technical data (to the extent that such items were originally furnished by the contractor) to incorporate the change and achieve the guaranteed MTBF.

(c) Additional "pipeline" unit spares to the Government on a consignment (no-charge loan) basis or payment for not providing consignment spares in accordance with Paragraph 5.6 for each type unit; however, the quantity of additional spares shall not exceed m as computed by the following formula:

$$m = (A \times S) - S_p$$

where

m = the maximum number of MTBF piepline consignment spare units (rounded to the next higher whole number)

S_p = spares currently consigned to the Government through the MTBF guarantee provisions

A = the number calculated as follows

$$A = \frac{G}{M} - 1 \text{ (if A is greater than 1, it shall be redefined as 1)}$$

G = specified unit MTBF guarantee value as defined in Paragraph 5.1 for the corresponding measurement period, as specified in Section E

M = achieved MTBF of unit

S = "target" spares level calculated as follows

$$S = \bar{N}\left(\frac{23 + T_r}{G}\right) AOT + 1.65\sqrt{\bar{N}\ \frac{23 + T_r}{G}\ AOT}$$

where 23 represents the number of pipeline days 12 to and from the Contractor's facility, and where T_r is the required contractor turnaround time as defined in Paragraph 3.7 and as specified in Section E. AOT represents the

average operating time of one (1) installed unit per day, as defined in Paragraph 3.8. If m is negative for a particular type of unit, the provisions of Paragraph 5.7 shall apply. The average number $\bar{N}$ of each type unit shall be calculated as set forth in Paragraph 3.8.

5.5 The objective of the consignment units is to support the pipeline flow pending improvement of the achieved MTBF. The Procuring Contracting Officer (PCO) shall determine the actual number of consignment spares to be provided by the contractor in the event that the unit MTBF guarantee value is not achieved. In no event shall the actual number exceed that computed by the formula in Paragraph 5.4.

5.6 In the event consignment units are to be supplied by the contractor to the Government, the contractor shall provide such units as soon as reasonably possible but not later than 90 days if the units are still in production, or 270 days if the units are not in production. 12 For each consignment unit that is not supplied within the appropriate time, the contractor will make payment at the rate of 1.67 percent of the unit price, specified in Section E, per day for each day late. In no event, however, shall this payment for any specific MTBF measurement period for the unit be more than 100 percent of the unit price.

5.7 In the event units have been consigned to the Government and "m" as calculated in Paragraph 5.4 hereof is negative during any one measurement period, all or a portion of such consignment units loaned to the Government under the MTBF guarantee provisions will be returned to the contractor according to the following formula:

$$\text{Number of Consignment Units to be Returned} = S_c - \left(\frac{G}{M} - 1\right) \times S$$

where

S_c = number of units currently on consignment; G, M, S are defined in Paragraph 5.4. In no event shall the number of consignment units to be returned exceed S_c.

5.8 Consignment units provided, pursuant to Paragraph 3.8 or Paragraph 5.6, which are in Government inventory, shall be subject to all provisions of the contract and the warranty at no increase in contract price. The warranty expiration date for such units shall coincide with the warranty expiration dates specified in the warranty herein. All consignment units required at the end of the warranty period, as determined in Paragraph 5.4, shall become the property of the Government at no additional cost to the Government.

5.9 Within sixty (60) days after the expiration of the warranty period, the contractor shall notify the PCO in writing of any consignment units or payment due the Government. On the basis of Government approval of the final measurement calculation, the contractor shall deliver all consignment units due, or with the approval of the PCO, pay the Government 100 percent of the value of any consignment unit(s) due.

PART VI - OPERATING-HOUR PRICE ADJUSTMENT

6.1 At the end of the second year and each year thereafter during the warranty period, the contract price shall be adjusted to account for actual operating hours over or under the projected total operating hours. Table D-1 presents the projected total operating hours by year and provides a sample calculation of operating-hour price adjustment. During any period in which the ratio of the actual to the projected total operating hours is between 0.9 and 1.1, there shall be no adjustment. 12 If the ratio is below 0.9, the price shall be adjusted downward by an amount equal to the projected operating hours minus the actual operating hours. The warranty price per operating hour will be computed by dividing the total 5-year warranty price by the projected 5-year total operating hours. If the actual operating hours in any measurement period are greater than 1.1 times the projected operating hours, the price shall be adjusted upward by an amount equal to the actual operating hours minus projected operating hours times the warranty price per operating hour. In no event shall the total adjustments during the warranty period be greater than 30 percent of the warranty price.

Table D-1. PROJECTED OPERATING TIME BY YEAR

Year	Projected Yearly Operating Time (Hours)
1	100,000
2	200,000
3	300,000
4	400,000
5	500,000
Total	1,500,000

Example of Operating-Hour Price Adjustment

If the warranty price is 1,500,000, the warranty price per operating hour would be $1. If at the end of the first two-year period the actual operating hours were:

- Between 270,000 and 330,000 hours, no adjustment would be necessary since the actual operating hours were between 0.9 and 1.1 of the projected total operating hours.
- For 250,000 hours, the downward adjustment would be

  (300,000 - 250,000) × $1 = $50,000

- For 375,000 hours, the upward adjustment would be

  (375,000 - 300,000) × $1 = $75,000

PART VII - DATA REQUIREMENTS

The following reports and/or plans are required: (14)

7.1 Data Collection Analysis and Reporting Plan/Program (DID, DI-L-30321A)

7.2 Material Transaction Contractor Storage/Distribution Point (DID, DI-L-30320)

EXPLANATORY COMMENTS FOR PROVISIONS

(1) Recent provisions, particularly in contracts awarded by AFLC, have included an Introduction section. The intent is to provide an overview of the provisions that follow in the remaining sections.

(2) Clarification of options and proposal pricing requirements for the separate options will normally be contained in the RFP instructions. For example, a third option could be an MTBF guarantee without a warranty. This type of guarantee was discussed in Subsection 7.2.1 of this report.

(3) A discussion of warranty coverage alternatives is contained in Subsection 7.1.1.5 of this report.

(4) For many items of ground equipment, an assumption of 24 or 8 operating hours per day per installed unit would closely approximate the actual operating hours.

(5) For equipments with relatively low demands on the supply system (i.e., high MTBF and relatively small quantities), it may not be cost-effective for the contractor to maintain a bonded storage area. In this case all items repaired by the contractor under warranty could be shipped to a centralized AF depot. The same comment applies to the requirement for the contractor operating an Autodin terminal to accomplish asset reporting.

(6) In lieu of citing certain data in Section J (Special Provisions) of the contract in many recent applications these data are contained in the contract schedule. An example of how the information would be displayed is shown below. The data entered in the example are for illustrative purposes only.

ITEM/ NOMENCLATURE	QUANTITY	UNIT PRICE	TOTAL PRICE	PRICE FOR WARRANTY OPTION ONLY	PRICE FOR MTBF GUARANTEE OPTION ONLY	PRICE FOR WARRANTY AND MTBF GUARANTEE OPTIONS	REPAIR TAT	GUARANTEED MTBF PERIOD 1	2	3
1	50	10,000	500,000	80,000	50,000	120,000	18 days	2800	3200	3500
2	100	5,000	500,000	65,000	30,000	80,000	10 days	4000	4500	5000

(7) As indicated in Subsection 7.1.1.2 of this report, specifications for Failure Verification and for Repair Verification Test Procedures may not have been prepared at the time of contract award. If this is the case, the provisions should indicate that the specifications are to be determined (TBD) and are subject to Government approval.

(8) For some units it may not be feasible to install seals (for example, on printed circuit boards). In these cases the conformal coating applied to the boards may serve as a seal, or alternative methods could be developed to indicate the presence of unauthorized maintenance. Alternative methods would also be required for identification plates and install/removal decals. If the warranty is at the module level, with modules defined to include boards, a reasonable approach would be to eliminate the requirement to record install/removal dates and assume a yearly total operating time.

(9) For critical equipment, or low sparing levels, the provisions could indicate that in no case will shipment occur more than 48 hours after receipt of the MRO.

(10) The number of "Retest OKs" expected will vary with individual items of equipment, adequacy of test equipment, etc. An alternative to this provision would be to state a certain percentage of "Retest Oks" that will be processed at no additional cost and to have the contractor quote a fixed price for processing "Retest Oks" above this percentage.

(11) If an MTBF guarantee is not applicable, an agreed-upon value may be used. In addition, if the average operating time per day computation is not practical, an assumed number, such as 24 or 8 hours per day, could be used for many items of ground equipment.

(12) Values typically used in recently awarded contracts.

(13) If demand does not justify an Autodin terminal, an alternative notification such as TWX may be stated.

(14) Copies of these Data Item Descriptions are shown in Appendixes F and G. As indicated in Subsection 7.1.2.6, required modifications to these DIDs would be dependent upon the specific application.

APPENDIX E

STATEMENT OF WORK (SOW) OUTLINE FOR USE WITH WARRANTY-GUARANTEE

As indicated in Chapter Seven, when a warranty-guarantee requires contractor maintenance at other than the depot level only, it may be necessary to prepare a separate statement of work (SOW) to describe the services to be performed. For example, at an operational site a contractor could provide warranty maintenance on equipment he had delivered and on other site equipment (GFE) provide maintenance under a services contract. Under these circumstances, or even if the contractor manufactured all the equipment, there are additional factors that must be covered independent of the warranty provisions. This appendix presents an outline for a SOW, which provides the general categories of information that must be covered; detailed information would depend on the specific application.

SECTION I: GENERAL

PART A

SCOPE

Part A would address, in general terms, the following items. Additional detailed information is provided in subsequent sections.

1. Types of equipments or systems and their operational locations

2. Services to be provided and any warranty/guarantee associated with these services

3. Designation of the technical representative of the contracting officer (TRCO) at each operational location

4. Statement of authority and responsibility of the TRCO in relation to the contractor

PART B

DEFINITION OF TERMS

Part B would define those terms and acronyms used within the SOW. The following terms are representative of those required:

1. Administrative Contracting Officer

2. Air Force Chief of Operating Location

3. Contractor Site Manager

4. Maintenance Services

5. Preventive Maintenance

6. Corrective Maintenance

7. Government Furnished Property

8. Contractor Furnished Property

PART C

GOVERNMENT FURNISHED ITEMS AND SERVICES

Part C would list those items and services to be provided by the Government, including:

1. Buildings and utilities
2. Office equipment, supplies, communications
3. Tools and test equipment
4. Ground-handling equipment
5. Spare parts and material
6. Government publications, including technical orders and forms
7. Calibration of test equipment

PART D

CONTRACTOR MANAGEMENT REQUIREMENTS

Part D would state the management requirements the contractor is expected to fulfill and could include the following:

1. Set minimum standards for employee qualifications
2. Provide organizational charts of the contractor work force
3. Evaluate operations, maintenance, personnel training, and performance for the purpose of improving operations and maintenance efficiency
4. Prepare recommended revisions to both Air Force and contractor directives
5. Establish new procedures and documentation when required by procedural changes
6. Recommend priorities for workload accomplishment
7. Establish and maintain quality assurance control in accordance with applicable Air Force directives
8. Prepare contingency plans for natural disasters, work stoppages, etc., that would adversely affect the ability of the contractor to perform required work

PART E

SECURITY

Requirements for personnel security clearance and day-to-day security matters should be cited and referenced to applicable security directives. Special security requirements for classified equipment or communications would also be included.

PART F

SAFETY

Safety requirements for both contractor personnel and Air Force operational personnel should be cited in relation to Air Force safety directives. Accident investigation and reporting procedures should also be cited.

PART G

PUBLICATIONS

Part G would list the publications applicable to the Statement of Work. It would also establish contractor responsibilities to maintain the necessary publication library. At a minimum, this would include equipment technical orders for equipment maintenance and supply manuals necessary for logistic support.

SECTION II: OPERATIONS

PART A

OPERATIONAL REQUIREMENTS

Part A would address the operational availability or maintainability requirements relative to the warranty-guarantee provisions. For example, the following is an extract from an actual contract in which a contractor is providing full maintenance on a remote radar station.

"1. The contractor shall provide the necessary services and maintenance to maintain an overall operational availability of at least 98 percent for the communications-electronics equipment specified in Section IV, Part A, of this statement of work.

2. Operational Availability will be calculated by the government as follows:

a. $$A_o = \frac{\text{Available Time - PM - CM - Testing}}{\text{Available Time}}$$

where

Available Time = 7 days/week, 24 hours/day

PM = Preventive Maintenance

CM = Corrective Maintenance

Testing = Time in which equipment testing causes that equipment to be non-operational or not within specified parameters

b. Equipment downtime resulting from government-caused delays (i.e., supply delays, military priorities, etc.), from government-directed actions such as TCTOs, from power shortages which are not caused by contractor action or non-action, or from acts of God shall not be included in 'Available Time.' "

Although the above example did not address a clearly defined penalty for the availability not being met, such a guarantee could be included in the warranty-guarantee provisions and referenced in the SOW.

PART B

EVALUATION

Part B would address the frequency and method required to evaluate contractor performance. For example, if the Equipment Status Reporting System were used for evaluating availability, a continuous record would be kept of downtime and certified by the Air Force Chief of the Operating Location.

SECTION III: LOGISTICS

PART A

SUPPLY

Part A would depend on the degree of contractor maintenance required under the contract. For example, if the contractor is totally responsible for all maintenance under warranty, he would be given the latitude of repairing all equipment at the operating location or, using his own supply procedures, of returning equipment to his intermediate or depot repair site.

Any contractor interface with the Air Force standard supply system would be contained in this section. For example, at a multiple equipment site where some equipment is maintained under warranty and other Government-owned equipment maintained under a fixed-price services contract, the contractor may be required to turn in reparable GFE and request replacement units. Contractor responsibilities for such reparable processing must be defined.

PART B

PROPERTY CONTROL

Part B would define the contractor responsibilities for control of any Government-supplied property or equipment. The following items are representative of those requiring accounting and reporting:

1. Bench stock
2. Tool cribs
3. Excess equipment and spares (including disposal actions)
4. Calibration of Precision Measuring Equipment (PME)
5. Marking and segregation of contractor-owned equipment

PART C

TRANSPORTATION

Transportation factors to be included in Part C are as follows:

1. Authorization regarding the use of Government Bills of Lading and franking privileges, if any.

2. Definition of vehicles, if any, to be provided by the Government. If vehicles are to be provided, restrictions on their use and maintenance responsibilities should be cited.

3. Special transportation requirements such as those unique to Precision Measuring Equipment.

4. Responsibility for and procedures to follow in packaging and crating Government property.

SECTION IV: EQUIPMENT MAINTENANCE REQUIREMENTS

PART A

EQUIPMENT

A list of all equipment (including the quantities of each type) for which the contractor is responsible should be contained in Part A. If any changes in the equipment quantities are planned, they should also be indicated. In addition, any modifications required, such as Time Compliance Technical Orders (TCTOs), should be listed.

PART B

MAINTENANCE REQUIREMENTS

Part B would address the level of maintenance required and associated maintenance management. For example, on some items of equipment the contractor could be responsible for all preventive and corrective maintenance, including both on- and off-equipment maintenance. On other items he may be responsible for on-equipment maintenance only (i.e., remove and replace) and may be required to return reparable units to a Government depot for repair. Maintenance management items would also be included, such as processing maintenance data collection (MDC) documents, material deficiency reports, configuration control, corrosion prevention and control, etc.

SECTION V: CIVIL ENGINEERING

Section V would address contractor responsibilities, if any, in the following areas:

1. Custodial services
2. Real Property Installed Equipment (RPIE)
   - Heating
   - Air conditioning
   - Standby emergency power
   - Electrical distribution and lighting
   - Plumbing
   - Water and drainage systems
3. Fire protection and fire fighting

APPENDIX F

DATA ITEM DESCRIPTION DI-L-30321A
RELIABILITY IMPROVEMENT WARRANTY (RIW)
DATA REPORTING AND SUMMARY REPORTS

The Data Item Description contained in the following pages is used to accumulate data on warranted equipment. The data permit the procurement activity to evaluate contractor compliance with warranty provisions and to make contract price adjustments.

DATA ITEM DESCRIPTION	2. IDENTIFICATION NO(S)	
	AGENCY	NUMBER
1. TITLE Reliability Improvement Warranty (RIW) Data Reporting and Summary Reports	USAF	DI-L-30321A

3. DESCRIPTION/PURPOSE

These data are used in the accumulation, processing, analysis and reporting of equipment failure data. Warranty data and summary reports are used to apprise the procuring agency of the type, severity, and frequency of failure occurring in activities under the cognizance of the contractor. Such data are necessary for evaluating the effectiveness of the Reliability Improvement Warranty concept and for providing information necessary for contract price adjustments.

4. APPROVAL DATE

11 January 1978

5. OFFICE OF PRIMARY RESPONSIBILITY

AFLC

6. DDC REQUIRED

7. APPLICATION/INTERRELATIONSHIP

This data item description is intended for use on all USAF procurements specifying a requirement for Reliability Improvement Warranty (RIW). Separate reporting requirements are included. Delivery instructions for each report must be identified separately on the Contract Data Requirements List (CDRL).
This DID supersedes DI-L-30321.

8. APPROVAL LIMITATION

9. REFERENCES (Mandatory as cited in block 10)

MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

10.1 Warranty Data Report. This report will contain as a minimum:

a. Program Summary. This part of the report will summarize the RIW program activity as follows:

(1) Program Detail - Display the RIW start date, reporting period start date and the reporting period cut-off date.

(2) Utilization Detail - Display the average quantity of installed systems, Average Operating Time (AOT) and Total Operating Hours (TOH).

(3) Repair Detail - Display the quantity of units returned subdivided by: exclusions (QTY/PCT), non-verified failures (QTY/PCT), and warranted failures (QTY); warranty units repaired and total repair days.

(4) Performance Statistics - Display achieved Mean Time Between Failures (MTBF) and average Turn Around Time (TAT).

(5) Program Status - Display by days and operating hours, contract warranty, warranty used and warranty remaining.

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10. Preparation Instructions (Cont'd)

b. Unit Summary. This part of the report will summarize the RIW activity for each type unit (Line Replaceable Unit (LRU)/ Shop Replaceable Unit (SRU)) as follows:

(1) Delivery/Processing Status - Display total units delivered, units returned subdivided by: exclusions (QTY/PCT), non-verified failures (QTY/PCT), and warranted failures (QTY); quantity in repair, quantity in secure storage, quantity reshipped, quantity condemned/lost, quantity on consignment, repair manhours, and repair parts and material costs.

(2) Utilization Detail - Display average quantity of units installed and Total Operating Hours (TOH).

(3) Unit Cycle Time - Display the logistics pipeline in average days for the following segments: shipment to contractor receipt, contractor receipt to storage, storage to shipment, shipment to installation, installation to removal, and removal to shipment.

(4) Unit Performance - Mean Time Between Failure (guaranteed/ achieved) Turn Around Time (guaranteed/achieved).

c. Unit/Detail. This part of the report will display by each type unit (LRU/SRU), historical activity of all delivered units as follows:

Unit serial number, date to storage, date of Material release Order (MRO), date shipped, elasped time indicator (ETI) reading out, configuration code, shipping destination, date installed, aircraft/equipment type and tail/serial number, date removed, date shipped to contractor, date received by contractor, originating activity, ETI reading in and RIW repair code (i.e. warranty exclusion, nonverified failure, warranty failure, etc.).

d. Failure Analysis: This part of the report will be a narrative analysis, by each type unit (LRU/SRU), of failures experienced, indicating modes, trends or patterns of failures and recommended/accomplished or projected corrective actions.

e. Modification Status Summary: This part of the report will display by each type unit (LRU/SRU) all Engineering Change Proposals (ECP's) submitted for reliability improvement as follows:

10. Preparation Instructions (Cont'd)

ECP number, date submitted, date approved, status code (i.e., govt approved, automatic approval, disapproved, etc.), configuration code, production effectivity (date and serial number), repair effectivity (date) and QTY/PCT of units affected and completed.

f. Consignment Spares Inventory: This part of the report will be a listing, indicating units (LRU/SRU) on consignment (loan) to the Government, including the noun serial number and date of consignment.

g. Other: This part of the report will include pertinent data, facts, information and investigation that the contractor, at his discretion, believes will be of value to the Government in implementing and expanding the RIW concept. Information concerning lost items or items declared nonrepairable shall also be included.

10.2 Warranty Effectiveness Report: A warranty effectiveness report shall be issued annually at the end of the reporting period. This report shall contain the contractors experience, analysis and conclusions regarding the effectiveness of the warranty. Particular attention shall be given to significant actions the contractor took, and the reason therefore, especially those he would not have taken on a contract without RIW. This report shall also contain recommendations regarding warranty clause provision which may be of mutual benefit to the Government and contractor.

10.3 Parts Consumption Report: An alpha-numerical listing of all parts contained in the equipment under warranty, indicating the total quantity of each part consumed during repair actions. Data displayed will include all repair actions from the warranty start date through the required report cut-off date.

10.4 Final Warranty Effectiveness Report: A bound, final warranty effectiveness report shall be issued after termination of the warranty program. This report shall contain all pertinent information summarized for easy understanding by those in Government or industry who are not familiar with RIW. It must also provide in appendix, full documentation to substantiate the conclusions and recommendations contained therein.

10.5 Data Collection, Analysis and Reporting Plan: A data collection, analysis and reporting plan shall be prepared detailing the data records to be maintained and the report format to be provided for each of the above reports.

APPENDIX G

DATA ITEM DESCRIPTION DI-L-30320
REPORTING MATERIEL TRANSACTIONS
CONTRACTOR STORAGE/DISTRIBUTION POINT

The Data Item Description contained in the following pages indicates the supply and accounting data reported by the contractor on USAF-owned assets being stored and repaired under the provisions of Reliability Improvement Warranty (RIW). The data are used by the Item Manager to maintain accountability of assets in the contractor's possession.

DATA ITEM DESCRIPTION	2. IDENTIFICATION NO(S)	
	AGENCY	NUMBER
1. TITLE Reporting Materiel Transactions Contractor Storage/ Distribution Point	USAF	DI-L-30320

3. DESCRIPTION/PURPOSE	
To provide transaction reporting of shipments, receipts, condition changes, etc., of USAF owned assets being stored and repaired under the provisions of Reliability Improvement Warranty (RIW).	4. APPROVAL DATE 8 APR 76 5. OFFICE OF PRIMARY RESPONSIBILITY AFLC 6. DDC REQUIRED 8. APPROVAL LIMITATION
7. APPLICATION/INTERRELATIONSHIP This data item description is intended for use on all USAF procurements specifying a requirement for Reliability Improvement Warranty (RIW). Replaces UL-83-MM	9. REFERENCES (Mandatory as cited in block 10) AFM 67-1, Vol I, Part One, Chapter 5. AFM 67-1, Vol III, Part Three, Chapters 4 & 17. DOD 4140.22-M. DOD 4140.17-M. MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

1. The contractor shall provide the following data to the government by AUTODIN/Advanced Record System:

a. Receipt Transaction (Serviceable) - Upon delivery of a production Spare Unit (LRU/SRU) to the bonded storeroom, transmit a receipt transaction in MILSTRAP format, attachment 1.

b. Receipt Transaction (Reparable) - Upon receipt of a failed unit (LRU/SRU) from a government activity, transmit a receipt transaction in MILSTRAP format, attachment 2.

c. Inventory Adjustment Transaction - Upon input of failed unit (LRU/SRU) to repair and/or completion of repair, transmit inventory adjustment transaction in MILSTRAP format, attachment 3.

d. Materiel Release Conformation/Denial - Upon receipt of Materiel Release Orders (MROs) from the Government, transmit shipment conformations/denials in MILSTRIP format, attachment 4 or 5.

2. Source documents, DD Form 1348-1, "DOD Single Line Item Release/Receipt Document," DD Form 1149,"Requisition and Invoice/Shipping Document," and contractor flow/repair documents utilized for the preparation and transmission of the above data will be retained by the contractor for government review/inspection.

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RECEIPT TRANSACTION FROM PROCUREMENT SOURCES

COLS	FIELD LEGEND	ENTER
1-3	Document Identifier	D4S
4-6	Routing Identifier (to)	ALC's Routing Identifier
7	Date	Per DD 250, block 3 (Note)
8-22	Stock Number	Per DD 250, block 16
23-24	Unit of Issue	Per DD 250, block 18
25-29	Quantity	Per DD 250, block 17 (prefix with zeros)
30-43	Contract Number	Per DD 250, block 1
44		Blank
45-50	Contract Line Item	Per DD 250, block 15
51-53	Mult-Use	001
54	Distribution	Year Code (7 for 1977)
55-56		Blank
57-59	Project Code	Per DD 250, block 14 (blank, if not applicable)
60-66	Contract Shipment Number	Per DD 250, block 2
67-69	Routing Identifier (from)	Contractor's Routing Identifier
70	Purpose Code	A
71	Condition Code	A
72		Blank
73-75	Date	Date received
76-80		Blank

NOTE: Alpha A, Jan; B, Feb; C, Mar; D, Apr; E, May; F, Jun; G, Jul; H, Aug; J, Sep; K, Oct; L, Nov; M, Dec.

(Preparation Instruction) RECEIPT TRANSACTION
(Reparable Receipt from the Government)

COLS	FIELD LEGEND	ENTER
1-2	Document Identifier	D6
3		Blank
4-6	Routing Identifier (to)	ALC's Routing Identifier
7		Blank
8-22	Stock Number	Data reflected in source document
23-24	Unit of Issue	Data reflected in source document
25-29	Quantity	Data reflected in source document (prefix with zeros)
30-44	Document Number	Data reflected in source document
45-50		Blank
51	Signal Code	Data reflected in source document
52-53	Fund Code	Data reflected in source document
54		H
55-56	Distribution	Data reflected in source document
57-59	Project Code	390
60-66	Base SRAN	Data same as in columns 30-36
67-69	Routing Identifier (from)	Contractor's Routing Identifier
70	Purpose Code	A
71	Condition Code	F
72	Management Code	H
73-75	Date	Date of receipt
76-80		Blank

INTER-CONDITION TRANSFER TRANSACTION

COLS	FIELD LEGEND	ENTER
1-3	Document Identifier	DAC
4-6	Routing Identifier (to)	ALC's Routing Identifier
7		Blank
8-22	Stock Number	Applicable Stock Number
23-24	Unit of Issue	EA
25-29	Quantity	Quantity (prefix with zeros)
30-43	Document Number	(See Note)
44-65		Blank
66	Condition Code (to)	A
67-69	Routing Identifier (to)	Contractor's Routing Identifier
70	Purpose Code	A
71	Condition Code (from)	F
72		Blank
73-75	Date	Transaction Date
76-80		Blank

NOTE: The doucment serial number will be obtained from a block of serial numbers furnished by the Government (e.g., 4016-4106). A sample document number would be FD206053224016.

COLS 30-35 - FD2060
36-39 - Julian Date
40-43 - Document Serial Number

MATERIAL RELEASE ORDER (MRO) CONFIRMATION

COLS	FIELD LEGEND	ENTER
1-3	Document Identifier	ARO
4-6	Routing Identifier (to)	ALC's Routing Identifier
7	Media and Status	Data reflected in MRO
8-22	Stock Number	Data reflected in MRO
23-24	Unit of Issue	EA
25-29	Quantity	Quantity shipped (prefix with zeros)
30-43	Document Number	Data reflected in MRO
44	Suffix	Data reflected in MRO
45-50	Supplementary Address	First six positions of the TCN (See Note)
51		Blank
52-53	Fund Code	Data reflected in MRO
54-56	Distribution Code	Data reflected in MRO
57-59	Date Shipped	Date material was shipped
60-61	Priority	Data reflected in MRO
62-64	Date	Date MRO received at contractor's facility
65-67	Routing Identifier (from)	Contractor's Routing Identifier
68-76	Transportation Control Number	Last nine positions of the TCN (See Note)
77	Mode of Shipment	Mode of shipment code (See Atch)
*78-80	Date	Date material was available for shipment

NOTE: The transportation control number (TCN) will be construct from the MRO document number. Using FB2065510560l2 as an example

COLS 45-50 would reflect B20655
68-76 would reflect 1056012XX

*Date material packaging was completed.

Atch

MODE OF SHIPMENT CODES

Code	Description
A	Motor, truckload
B	Motor, less truckload
C	Van (unpacked, uncrated personal and/or government property
D	Driveaway, truckaway, towaway
E	Busline
F	Military Airlift Command (MAC)
G	Parcel Post, surface
H	Parcel Post, air
I	Government truck, including common service
J	REA express
K	Rail, carload
L	Rail, less carload
M	Freight forwarder
N	LOGAIR
O	Organic military air
P	Through bill of lading
Q	Air freight
R	Air express
S	Air charter
T	Air freight forwarder
U	QUICKTRANS
V	Sea-van service
W	Water, river, lake, coastal (commercial)
X	Sealift Express Service (SEA-EX) (Note: Not to be shown on TCMDs; for use in shipment status and tracing only).
Z	MSTS (controlled/contract/arranged space)
2	Government watercraft, barge/lighter
3	Roll on/roll off service
4	Armed Forces Courier Service (ARFCOS)
5	United Parcel Service
6	Military Official Mail (MOM)
7	Weapon System Pouch Service
8	PIPELINE
9	Local delivery, including deliveries between air or water terminals and adjacent activities.
*	Pilot pick-up of FMS materiel by foreign country aircraft (for AF assignment only).

MATERIAL RELEASE ORDER (MRO) DENIAL

COLS	FIELD LEGEND	ENTER
1-3	Document Identifier	Col. 1--Data reflected in MRO; Col. 2-6; Col. 3-Data reflected in MRO
4-6	Routing Identifier (to)	ALC's Routing Identifier
7	Media and Status	Data reflected in MRO
8-22	Stock Number	Data reflected in MRO
23-24	Unit of Issue	Data reflected in MRO
25-29	Quantity	Quantity being denied (prefix with zeros)
30-43	Document Number	Data reflected in MRO
44	Suffix	Data reflected in MRO
45-50	Supplementary Address	Data reflected in MRO
51	Signal Code	Data reflected in MRO
52-66		Blank
67-69	Routing Identifier (from)	Contractor's Routing Identifier
70	Ownership Code	Data reflected in MRO
71	Condition Code	Data reflected in MRO
72	Management Code	Data reflected in MRO
73-80		Blank

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